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ABSTRACT

This manual presents a simple, step-by-step description of irrigated rice production in Sierra Leone. It is geared specifically to the role and needs of Peace Corps volunteers who, since the mid-1970s, have worked as agricultural extension agents in the Sierra Leone Ministry of Agriculture and Forestry. The manual is designed to serve both as a training manual, complementing the curriculum taught during preservice training, and as a field guide that contains a ready source of technical information during the growing season. The 18 chapters in the manual cover the stages of rice plant growth, seed selection and preparation, land preparation, fertilizer, insect pest prevention, diseases of rice, weed control, harvesting, threshing, drying, and storage. References and a glossary complete the manual. (KC)

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Peace Corps

RICE PRODUCTION

A Training Manual and Field Guide to Small-Farm Irrigated Rice Production

Developed by Peace Corps/Sierra Leone
Edited by Michael L. Morris

Peace Corps
Information Collection and Exchange
Reprint R 40
July 1980
September 1982

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Introduction

This manual presents a simple, step-by-step description of irrigated rice production in Sierra Leone. It is geared specifically to the role and needs of Peace Corps Volunteers, who since the mid-1970's have worked as agriculture extension agents in the Sierra Leone Ministry of Agriculture and Forestry (MAF). Placed in rural areas throughout the country, Volunteers work with local farmers as advisors, co-workers, and friends in helping introduce a new farming technology: water control agriculture. As extension agents, their role includes surveying undeveloped swamps, designing effective water control systems, and teaching farmers productive and appropriate rice cultivation practices.

This manual is intended to serve a dual purpose. As a training manual, it should complement the curriculum taught during pre-service training. As a field guide, it should provide a ready source of technical information during the growing season.

Because most Peace Corps Volunteers entering the Sierra Leone agriculture program have no formal background or training in tropical agriculture, the descriptions and "technical" explanations have been greatly simplified throughout. While detailed technical material on irrigated rice production is abundantly available, simplified sources are rare or nonexistant. This manual is designed to fill that void. The Volunteer who is able to grasp the information contained in these pages will possess more than enough technical expertise to serve as an effective extension agent. For those interested in reviewing more technically-oriented material, such material is abundantly available from sources such as: Ministry of Agriculture and Forestry Stations, the Peace Corps Resource Center in Freetown, Rokupr Rice Research Station, Njala University College, Peace Corps Information Collection and Exchange (ICE).

* * *

This manual was first assembled (from a variety of sources) in September, 1978 by a group of Peace Corps Volunteers including: Phil Aaker, Mark Carroll, Joe Conn, Michael Morris, Brian Morrison, Dan Nagengast, Dick Walker, and Lee White. Jeff Hill later read sections of the draft and offered comments. It was revised and extensively edited in April, 1980 by Michael Morris.

CHAPTER 1

RICE MORPHOLOGY

Introduction

For many of you, this will be your first exposure to rice as a plant. This chapter provides a brief introduction to the physical parts of the rice plant -- what botanists call the morphology. It is intended to be neither highly technical nor comprehensive. A basic understanding of the physical characteristics of the rice plant will facilitate your understanding of the rice growth cycle and should prove useful in many aspects of cultivation.

Outline of Contents

I. General Information
II. Roots
III. Stem and Leaves
IV. Reproductive Organs
V. Grain

I. General Information

Rice (oryza sativa) belongs to the family of cereal grasses, along with wheat, corn, millet, oats, barley, rye, and numerous others. The grass family provides the world with over 60% of its caloric intake and over 75% of the protein for developing nations.

The rice plant is an annual grass (it normally grows for only a year and then dies) with round, hollow, jointed culms (stems), flat leaves, and a terminal panicle (flower cluster). It is the only cultivated cereal plant adapted to growing in both flooded and non-flooded soils. Grown under a wide range of climatic and geographical conditions on all five continents, it serves as the staple food throughout much of the world.

The parts of the rice plant may be divided as follows:

- roots
- stem and leaves
- reproductive organs
- grain

II. Roots

As the underground portion of the plant, the roots serve as support, draw food and water from the soil, and store food. They are fibrous and consist of rootlets and root hairs. The embryonic roots, or those which grow out of the seed when it germinates, have few branches. They live for only a short time after germination. Secondary adventitious roots (i.e. roots appearing in an irregular pattern) emerge from the underground nodes of the young culm and replace the embryonic roots. Although a few adventitious roots grow straight down to a depth of over 15", most spread out under flooded conditions into the shallow oxidized soil layer near the surface to form a broad, dense network.

III. Stem and Leaves

a) Stem

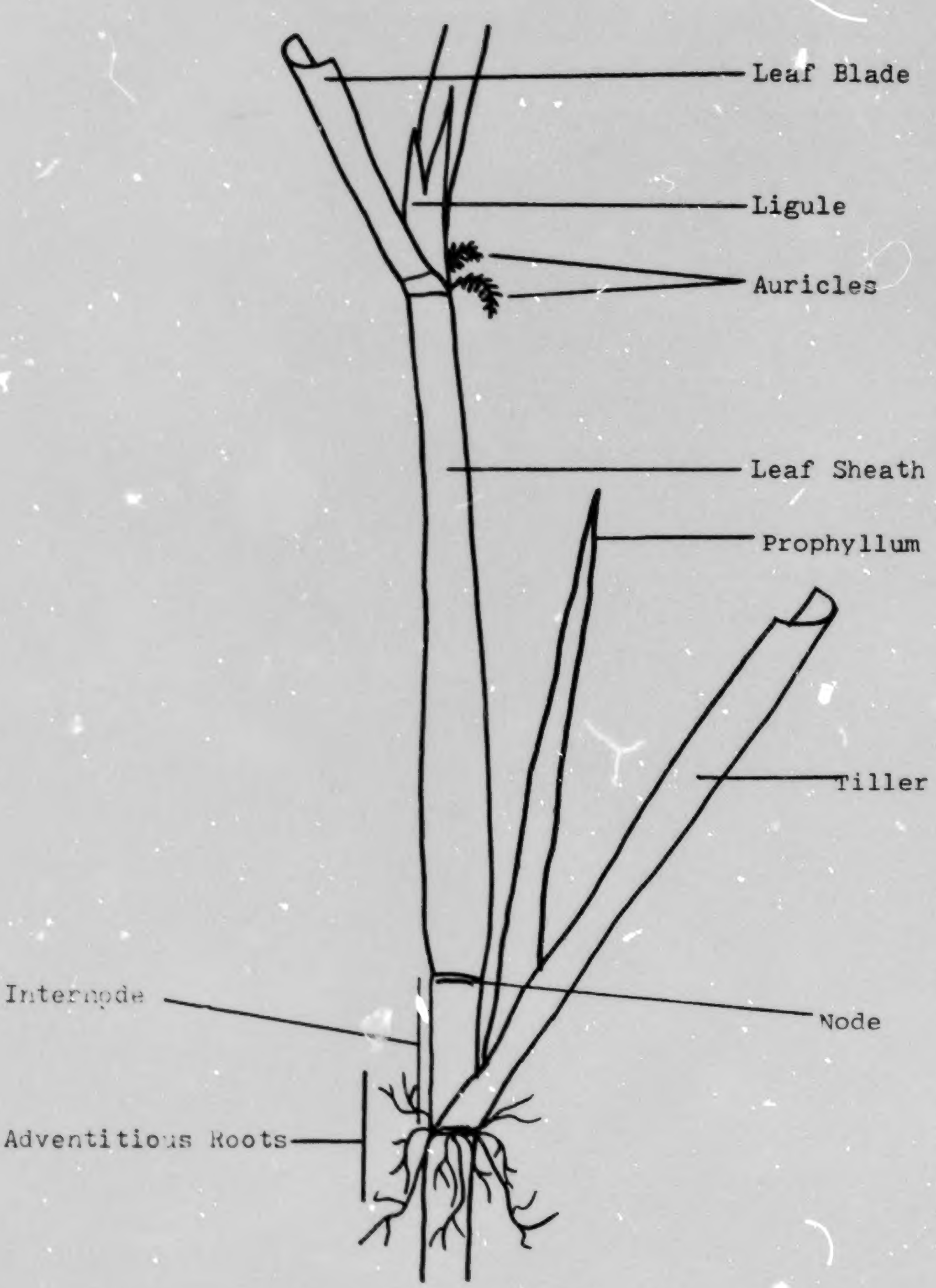
The role of the stem (or culm) is to support the leaves and reproductive structures, and to transfer essential nutrients between the roots, the leaves, and the reproductive structures. The stem is made up of a series of nodes and internodes in alternating order. The node (corresponding to the "joint" between two sections of the stem) bears a leaf and a bud which, if it is on the lowermost node, may grow into a tiller, or shoot. The mature internode is hollow and finely grooved. Its outer surface is hairless. It varies in length, generally increasing from the lower to the upper internodes. The lower internodes at the base of the stem are short and thickened into a solid section. The internodes have the capacity to elongate in deep water in order to keep a portion of the plant above water to carry on photosynthesis.

b) Leaves

The leaves function as the principal organs of photosynthesis and respiration (i.e. they contain chlorophyll-containing cells which convert sunlight to chemical energy and synthesize organic "fuel" compounds from inorganic compounds). The leaves are borne at an angle on the stem in two ranks -- one at each node. The blade, or extended part of the leaf, is attached to the node by the leaf sheath. The sheath envelops the internode toward, and in some cases even beyond, the next node. On either side of the base of the blade are pairs of small, earlike appendages known as auricles. Just above the auricles is a tissue-like, triangular structure called the ligule. Rice plants have both auricles and ligules and a ligule at every internode; this characteristic is often helpful in differentiating between rice and grassy weeds, which can have auricles or a ligule, but not both.

The uppermost leaf below the panicle, the flag leaf, provides the most important source of photosynthetic energy during reproduction.

Fig. 1: Stem and Leaves of Rice


Leaf Blade
Ligule
Auricles
Leaf Sheath
Prophyllum
Tiller
Internode
Node
Adventitious Roots

III. Reproductive Organs

a) Panicle

The panicle, or flower cluster, contains the reproductive organs of the rice plant. Borne atop the uppermost node on the stem, the panicle is divided into primary, secondary, and sometimes tertiary branches bearing the spikelets. The branches may be arranged singly or in pairs. The panicle stands erect at blooming, but it usually drops as the spikelets fill, mature, and develop into grains. Varieties differ greatly in the length, shape, and angle of the primary branches, as well as in the weight of the overall panicle.

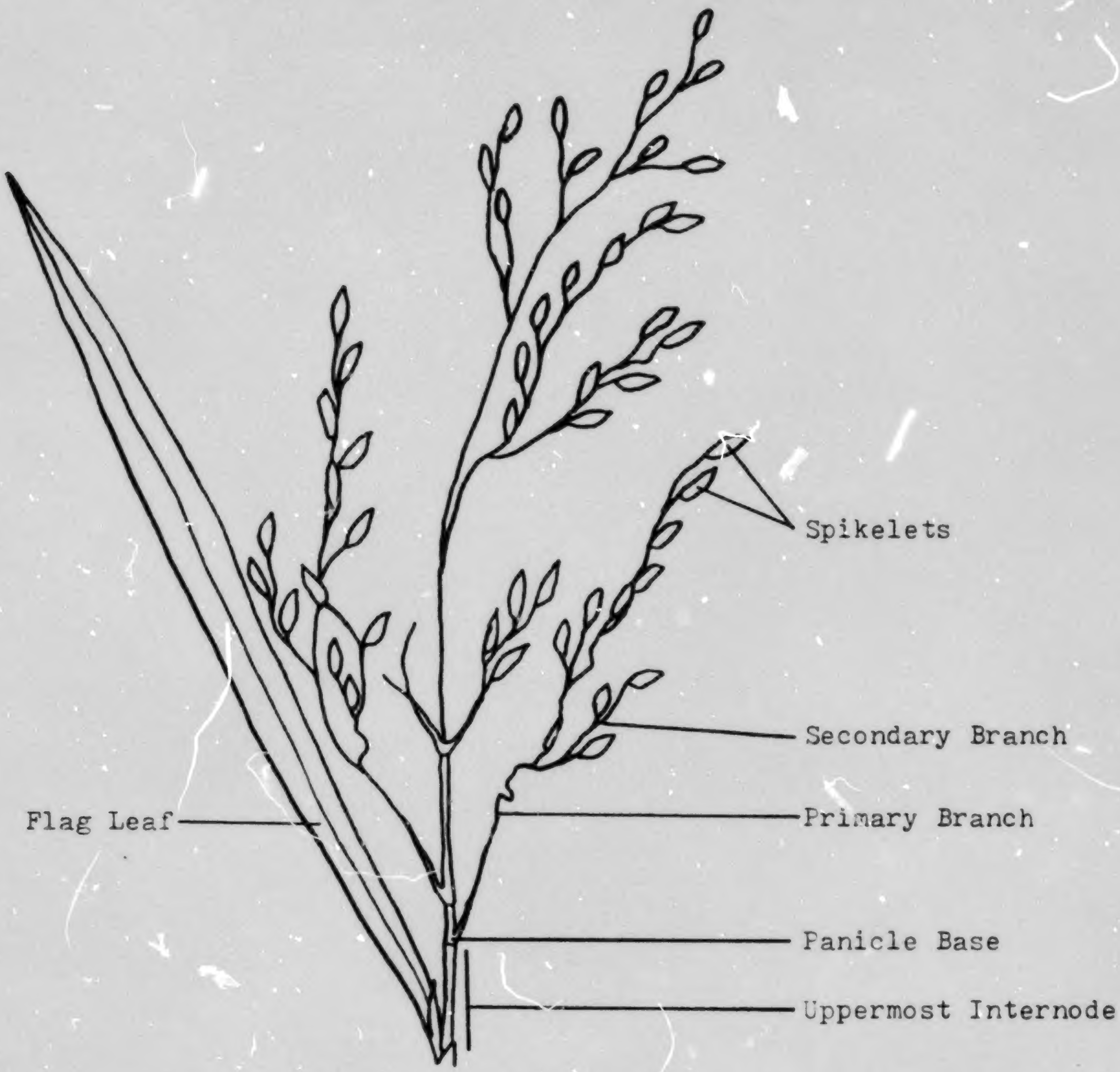

Spikelets
Secondary Branch
Flag Leaf
Primary Branch
Panicle Base
Uppermost Internode

Fig. 2: The Panicle (partly shown)

b) Spikelet

Each individual spikelet contains a set of floral parts flanked by the lemma and palea. The flower consists of six stamens and a pistil. The stamens (which contain pollen, or "sperm") are composed of two-celled anthers borne on slender filaments. The pistil consists of the ovary (containing the ovule, or "egg"), the style, and the stigma. During reproduction, the stigma catches pollen from the stamens and conducts it down to the ovary, where it comes into contact with the ovule and fertilization occurs.

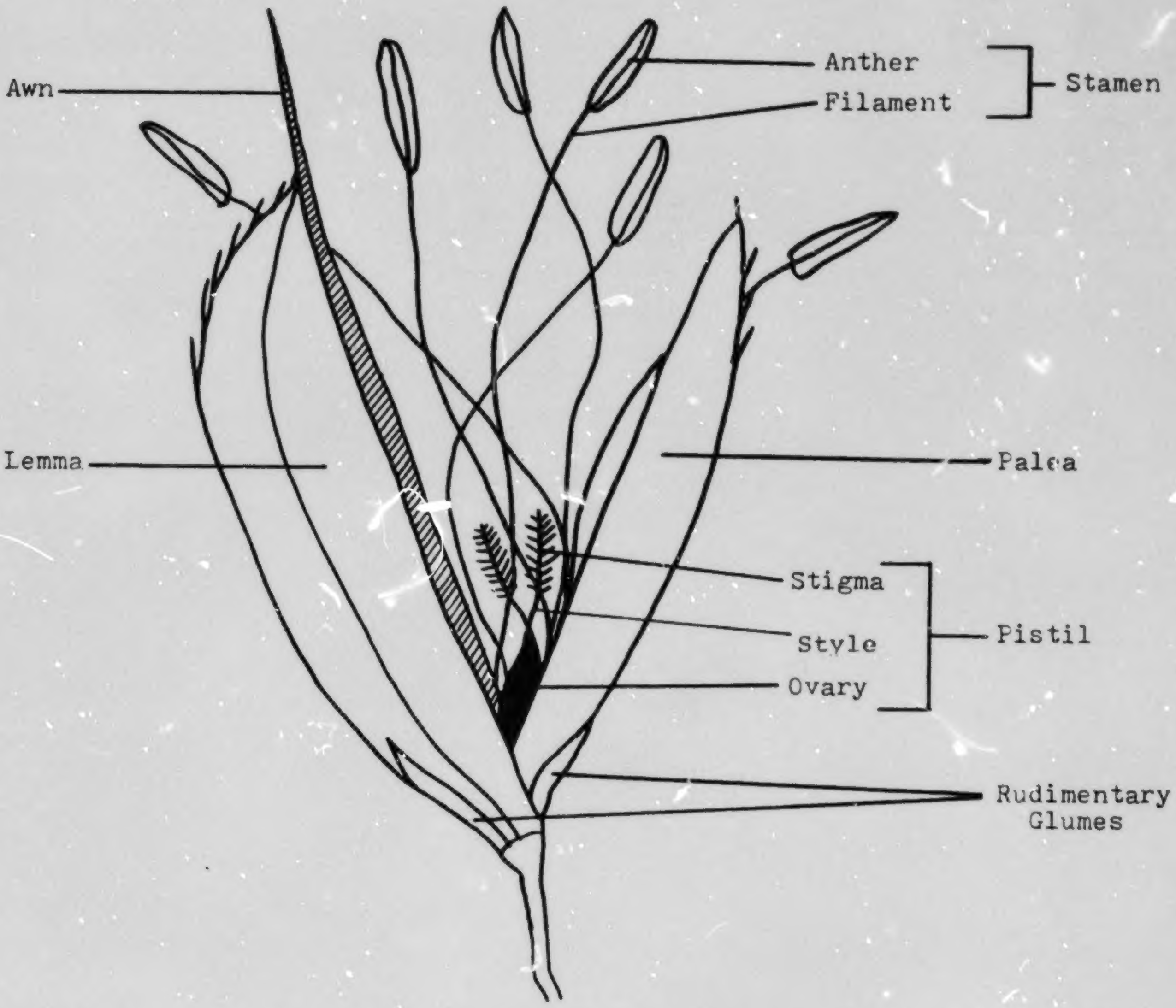

Awn
Anther
Filament
Stamen
Lemma
Palea
Stigma
Style
Ovary
Pistil
Rudimentary Glumes

Fig. 3: The Spikelet

V. Grain

The grain is the seed of the rice plant, a fertilized and ripened ovule containing a live embryo capable of germinating to produce a new plant. It is composed of the ripened ovary, the lemma and palea, the rachilla, the sterile lemmas, and the awn (not always present). The lemma and palea and their associated structures constitute the hull or husk. The embryo lies at the ventral side of the spikelet next to the lemma and contains the embryonic root. The rest of the grain consists largely of endosperm (the edible portion), containing starch, proteins, sugar, fats, crude fiber, and inorganic matter.

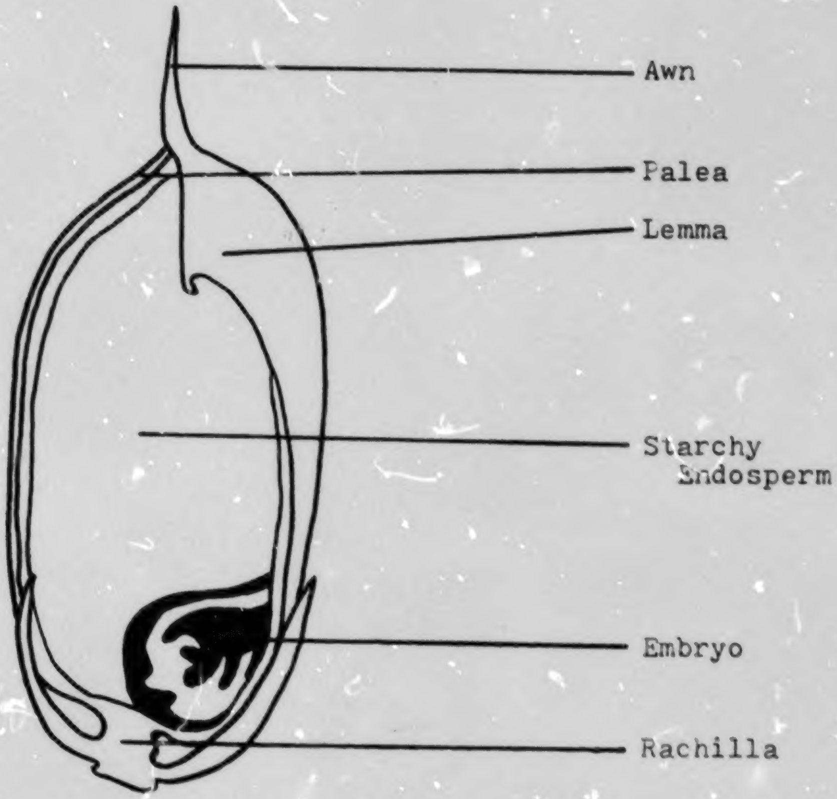


Fig. 4: The Grain

CHAPTER 2

THE GROWTH STAGES OF RICE

Introduction

The growth cycle of the rice plant begins with fertilization and subsequent development of the embryo nucleus. With the introduction of heat and moisture, the embryo germinates and develops into a seedling. Feeding initially on the food supply contained within the grain (endosperm) and later drawing nutrients from the air and soil, the seedling grows into an adult plant which eventually produces flowers and then seeds. The extension agent must be able to recognize and understand the growth stages of rice in order to time management practices properly (e.g. transplanting, irrigation, fertilization, weeding, harvesting).

Outline of Contents

I. The Vegetative Phase
II. The Reproductive Phase
III. The Ripening Phase
IV. Chart: The Growth Stages of Rice

I. The Vegetative Phase

The vegetative phase begins with germination and ends with panicle initiation. Unlike the reproductive and maturity phases, which are of equal duration for all rice varieties, the vegetative phase varies considerably in length and can last from 21 days to over 10 months. The vegetative phase can be divided into four stages:

a) Seedling Stage

The seedling stage begins with the emergence of the radicle and lasts until the onset of tillering, usually a period of 15-30 days depending on seed preparation practices, nursing techniques, nutrient inputs, and climatic conditions. During the early part of the seedling stage the plant's root system undergoes rapid and extensive growth; once the root system is able to draw nutrients from the soil, a substantial growth of the leaf surface follows. In rice nursed for transplanting, the appearance of the fourth leaf is generally considered to signal the end of the seedling stage.

b) The Transplanting Stage

The so-called transplanting stage is not really a natural stage at all but represents the 5-10 day period of growth impairment caused by the shock to the seedling of uprooting and transplanting. The transplanting stage can be shortened significantly by gentle handling of the seedlings and by early transplanting (younger plants recover most rapidly from the shock of uprooting because their relatively undeveloped root systems suffer little damage).

c) The Tillering Stage

The tillering stage begins with the appearance of the first tiller or shoot from the auxiliary bud on the lowermost internode. The tillering stage continues on through the formation of secondary and tertiary tillers. The number of tillers produced by a plant varies and is affected by genetic determinants, the availability of nutrients (including water and sunlight), and the general health of the plant. The tillering stage continues up to the point of maximum tillering, at which all effective tillers have been produced (an effective tiller is one which bears a panicle on which the grains will ripen fully).

d) The Photoperiod Sensitive Stage

The photoperiod sensitive stage lasts from the point of maximum tillering until panicle initiation and may vary extremely from one variety to the next (as much as 0-200 days). Photoperiod sensitivity is a natural mechanism based on the plant's ability to distinguish precise differences in daylength/nightlength. Photoperiod sensitivity ensures that the plant will enter its reproductive phase at the optimal time of year, i.e. when temperature and moisture will permit successful reproduction (in temperate zones this is usually in spring or early summer, in the tropics usually during the onset of the seasonal rains). The biological mechanism causing photoperiod sensitivity is quite complex and need not be explained in detail. It is important simply that the extension agent understand the effect of photoperiod sensitivity: namely, that some varieties should be planted only during certain times of year to ensure that prevailing daylength/nightlength conditions will trigger panicle initiation when desired. Consult local authorities for information about which locally grown varieties are photoperiod sensitive.

II. The Reproductive Phase

The reproductive phase includes the period during which the panicle forms and emerges from the base of the tiller. The reproductive phase begins at panicle initiation, when the panicle begins to develop at the end of the last internode deep inside a protective covering of leaf sheaths. The reproductive phase lasts approximately 45 days among all varieties and can be divided into three stages:

a) The Booting Stage (Internode Elongation Stage)

By the time the panicle becomes visible to the naked eye (as a tiny, transparent growth less than 2mm in length buried within the leaf sheaths near the base of the plant), the booting stage is already underway. During the booting stage, which lasts approximately 15-20 days among all rice varieties, the internodes undergo a rapid growth spurt and quickly lengthen (like a radio aerial extending), causing the culm to shoot up from the base of the plant bearing the developing panicle. During this period of rapid growth the plant's demand for nutrients is high, making the early booting stage a crucial time for fertilization. However, it is sometimes difficult to detect panicle initiation and the earliest onset of booting. When in doubt consult the farmer, who will often be able to tell when the rice has "become pregnant."

b) The Heading Stage

The booting stage is followed by the emergence of the panicle from the protective flag leaf sheath. The heading stage lasts until 90% of the panicles have emerged from their sheaths -- generally about 10 days in most varieties.

c) The Flowering Stage

The flowering stage begins with the emergence of the first anthers from the uppermost spikelets on each panicle. Each individual spikelet flowers for only several hours during the middle of the day on two or three successive days. Flowering begins among the uppermost spikelets and continues for approximately 15 days regardless of variety as the remaining spikelets successively open (the lowermost spikelets flowering last). During flowering, pollen from the anthers is transported by wind and insects to the stigma, which carry it down into the ovaries where fertilization of the ovules occurs.
(Note: Never apply fertilizer or pesticide during periods of active flowering, as the pollenization process is extremely sensitive and can easily be disrupted by the presence of agro-chemicals.)

III. The Ripening Phase

The ripening phase begins at fertilization and continues through grain filling and ripening, approximately 25-35 days regardless of variety. Grain filling occurs as nutrients and water are transported from one part of the plant to another; the process is affected by the availability of water and nutrients, and by temperature. Grain filling and ripening can be broken down into four stages:

a) The Milk Stage

The endosperm first begins to form as a milky liquid. Rice at the milk stage is very susceptible to attack by sucking insect pests.

b) The Dough Stage

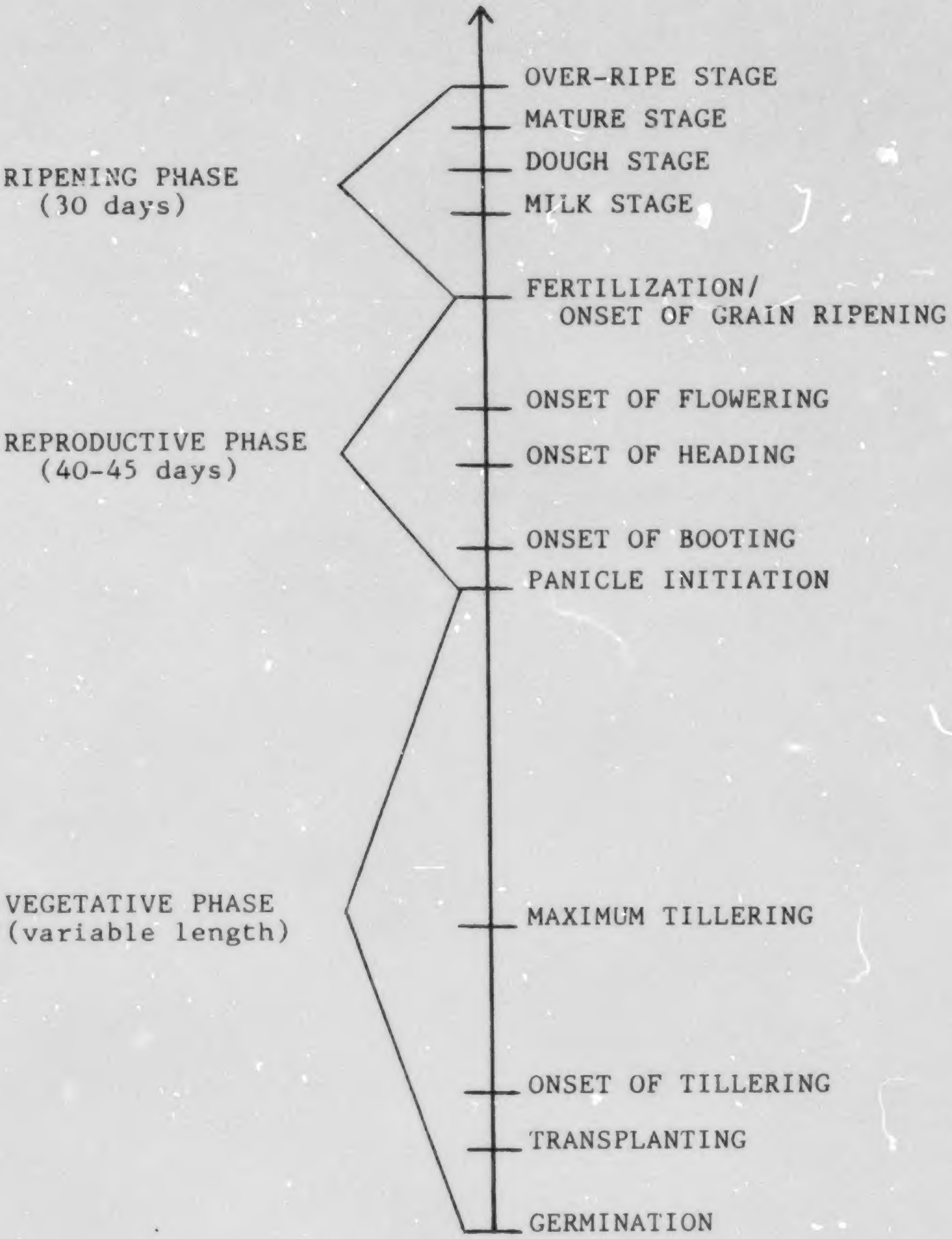
The milky liquid begins to solidify into a sticky white paste. Bird pests generally begin to be a serious problem.

c) The Maturity Stage

The grain is mature, or ripe, when the endosperm becomes hard and opaque. While the grains ripen, the leaves of the plant begin to turn yellow as nitrogen is transferred from the leaves to the seed. The full maturity stage is reached when more than 90% of the grains in the panicles have ripened. Mature grains usually undergo a change in color and turn a golden brown, but under wet climatic conditions ripe grains may remain somewhat greenish.

d) The Over-ripe Stage

If the grains are not harvested on time, the vegetative parts of the plant -- stems, leaves, and roots -- begin to die off. Then the over-ripe grains fall off the panicles onto the ground in a process known as shattering. Some rice varieties are particularly susceptible to shattering, and serious crop losses may occur if harvesting is not completed on time. In rare instances, over-ripe grains left too long on the panicle may undergo germination (varieties exhibiting this characteristic are said to lack dormancy).


OVER-RIPE STAGE
MATURE STAGE
DOUGH STAGE
MILK STAGE
RIPENING PHASE
(30 days)
FERTILIZATION/
ONSET OF GRAIN RIPENING
ONSET OF FLOWERING
REPRODUCTIVE PHASE
(40-45 days)
ONSET OF HEADING
ONSET OF BOOTING
PANICLE INITIATION
VEGETATIVE PHASE
(variable length)
MAXIMUM TILLERING
ONSET OF TILLERING
TRANSPLANTING
GERMINATION

IV. CHART: THE GROWTH STAGES OF RICE

CHAPTER 3

VARIETAL CHARACTERISTICS

Introduction

A vast number of rice varieties is grown around the world. While it is true that no "perfect" variety exists, for every combination of environmental features, management practices, and farmer preferences it is usually possible to select a suitable variety. This chapter describes the kind of things to look at when you select a rice variety. Like the farmer, you will find yourself relying both on tradition and on trial and error. The traditional varieties provide the security of known responses that have proven themselves over the years. The trials and errors are what make the work creative and offer the hope of improvement.

Outline of Contents

I. Varietal Characteristics
II. Traditional vs. Improved Varieties
III. Chart -- Locally Available Varieties

I. Varietal Characteristics

Listed below are the varietal characteristics most often considered by farmers in selecting a rice variety for cultivation:

a) Duration - most cultivated varieties range from 90-270 days in duration (germination to harvest)
Importance:
- *determines how many crops can be grown in one year
- *important in coordinating the growing season with the availability of water
- *important in coordinating the farming calendar with other family subsistence activities

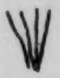
b) Height of the Plant - rice varieties are generally classified by height as follows:

tall	161cm - 350cm	(63" - 140")
medium	75cm - 160cm	(30" - 62")
short	below 75cm	(below 30")

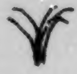
Importance: *determines crop's ability to withstand deep flooding
*affects harvesting practices

c) Stature of the Plant - rice varieties are generally classified by stature as follows:

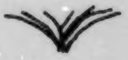
upright



slightly spreading



spreading



Importance: *affects spacing during planting
*determines plant's ability to shade out competing weeds

d) Tillering Capacity - rice varieties are said to be either:

high tillering (each seed produces 26-35 tillers)
medium tillering (each seed produces 10-25 tillers)
low tillering (each seed produces 2-10 tillers)

Importance: *directly affects yield
*determines planting practices
*determines amount of seed nursed
*affects plant's ability to recover from damage inflicted by pests or weather

e) Panicle Size/Grain Weight

Importance: *directly affects yields

f) Resistance to Toxicities

Importance: *determines suitability to local soil and water conditions

g) Resistance to Pests/Diseases

Importance: *determines suitability to local pest/disease conditions

h) Response to Fertilizer - many improved varieties have been bred to respond favorably to fertilization with chemical fertilizers, i.e. they show a marked increase in growth rate, height, number of tillers, panicle size, and grain weight.

Importance: *should be compatible with farmer's fertilization practices (or non-fertilization practices)

i) Milling and Cooking Characteristics - depending on the nature of the husk, rice varieties may be either easy or difficult to mill. Furthermore, cooked rices vary considerably in appearance, texture, taste, smell, and starch content.

Importance: *significantly affects farmer's preferences

II. Traditional vs. Improved Varieties

In many parts of the world, farmers have been growing rice for hundreds or even thousands of years. During this time, many varieties have interbred or mutated and gradually adapted to local conditions. Conversely, through trial and error farmers have developed traditions of cultivation practices which assure consistent fair yields with relatively little management. The majority of subsistence farmers still rely on time-honored management practices to cultivate their traditional varieties. Characteristics typically found in such varieties include:

- long duration
- high tillering
- spreading stature
- resistance to drought/flooding
- resistance to pests/diseases
- competitive with weeds
- adapted to low nutrient levels
- high milling and cooking quality

Although the traditional varieties usually yield lower than the improved varieties, the extension agent should be extremely careful about suddenly encouraging farmers to abandon a time-tried variety for one which differs considerably from what they are used to growing. The single most important characteristic of most traditional varieties is their ability to produce sustained yields, however modest. The introduction of a new "miracle" variety, even if advantageous initially, may prove disastrous in the long run if the farming system over time proves incapable of providing the nutrient inputs necessary for the production of sustained high yields. As a rule, high yields require high (fertilizer) inputs, and it is easy to make the mistake of either creating a fertilizer dependency or depleting a balanced farming ecosystem by introducing a variety which extracts nutrients faster than they are being replenished. The extension agent should not be afraid to experiment with new varieties -- but s/he must be careful not to encourage the farmer to succomb to the short-sighted temptation to maximize present yields. The traditional varieties, however low-yielding, have endured over thousands of years because they are hardy, reliable, and ecologically safe.

III. Chart - Locally Available Varieties

VARIETY	DURATION	RECOMMENDED		HEIGHT	TILLERS	GENERAL: Toxicity/Pest/Disease Resistance; Response to Fertilizer; Etc.
		WET	DRY			

VARIETY	DURATION	RECOMMENDED		HEIGHT	TILLERS	GENERAL: Toxicity/Pest/Disease Resistance; Response to Fertilizer; Etc.
		WET	DRY			

CHAPTER 4

SEED SELECTION AND PREPARATION

Introduction

Because better seed results in healthier seedlings which may lead to higher yields, the importance of planting only the highest quality seed cannot be overemphasized. Seedling vitality in the early growth stages is largely the result of careful seed selection and preparation. Furthermore, since seed cost and availability are often two major economic constraints to small farmers, it is important that they know how to calculate the precise amount of seed needed to plant their farms. One of the most effective ways to improve a farmer's yield and to help derive maximum utility from his limited resources is by teaching him to select only the best available seed, to calculate precisely the quantity he will need, and to prepare a good seed sample for sowing.

Outline of Contents

I. Selecting Rice Seed
II. Testing the Germination Rate
III. Soaking and Incubating Seed
IV. Calculating Seed Requirements

I. Selecting Rice Seed

Only the best seed should be selected for planting for the following reasons:

- good seed results in healthier, heavier, and potentially higher-yielding seedlings.
- good seed results in seedlings which recover quickly from transplanting shock.
- good seed results in rapid root growth, enabling seedlings to draw nutrients from the soil quickly and effectively.
- good seed results in uniform germination and growth of seedlings, making it easier for the farmer to time crop management practices (e.g. transplanting, irrigation, fertilization, weeding).
- good seed has a high germination rate, facilitating exact calculation of seed requirements and thus preventing wastage due to nursing of too few or too many seedlings.

A good sample of rice seed should be:

- genetically pure (Genetic purity cannot always be determined by visual inspection; the best way to ensure genetic purity is by obtaining seed from a reliable source -- e.g. the Ministry of Agriculture, an international agricultural organization -- or by encouraging farmers to produce their own seed.)
- dried to less than 14% moisture content (since improperly dried seed often rots during storage.)
- capable of germinating at a rate of at least 80% (since it is usually uneconomical to plant seed if a considerable portion will not germinate.)
- free of weed seeds
- free of diseases
- free of pest infestation
- free of inert matter (e.g. chaff, empty grains, grit, broken grains.)

Important: When dealing with seed of unknown origin, always remember that it is often impossible to evaluate a seed sample merely by looking at it. Genetic impurities, improper dryness, disease contamination, and pest infestation often do not manifest themselves until the seed is sown and has started to grow. Be sure to test a small portion of the sample (by actually growing an experimental plot) to ensure that the seed is acceptable. Never commit a farmer to growing seed which may turn out to be of poor quality.

II. Testing the Germination Rate

When the time comes to calculate how much seed rice will be needed to plant a particular area, it will be important to know what percentage of the available seed will actually germinate. Seed may not germinate for several reasons: it may be dormant (incapable of germinating until a minimum interval has elapsed after the seed matured), or it may no longer be viable (the embryo may no longer be alive). When dealing with a seed of unknown age and quality, it is always a safe bet to test the germination rate to avoid wasting money, time, and effort in replanting if the sample fails to germinate well.

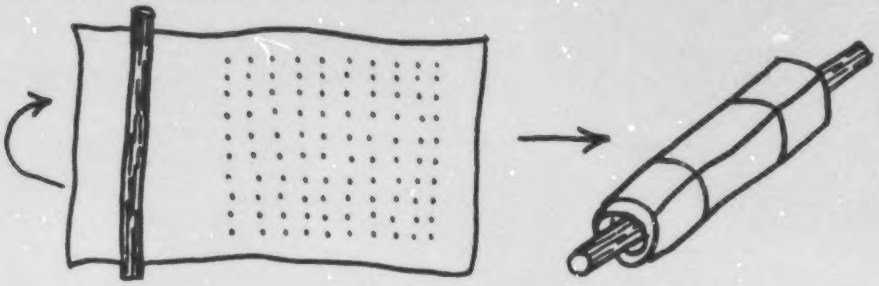
Various germination tests can be performed to determine germination rates. One of the simplest and most inexpensive tests -- and one that many farmers can learn to do themselves -- is the Rag Doll Test.

(Materials required: several teaspoonsful of the seed to be tested, 3-5 hankerchief-sized rags, 3-5 small sticks, several short lengths of string.)

1) Soak the rags in clean water and spread them out on a flat surface.

2) From the seed sample, count out exactly 100 grains for each rag and distribute the grains evenly around the cloth (ten rows of ten grains facilitates counting.)

3) Carefully roll each rag around a separate stick, leaving the seeds undisturbed inside.



4) Fasten the rags to the sticks with string and store the finished Rag Dolls in a warm moist place for five (5) days.

5) Moisten the cloth several times every day (this is very important; if the Rag Dolls are allowed to dry out, the seeds will die.)

6) After five (5) days, unroll the rags and count the number of seeds with roots. If each Rag Doll contains exactly 100 seeds, the number of sprouted seeds will equal the germination rate of the sample (e.g. if 85 seeds out of 100 sprouted, the germination rate equals 85%)

7) Average out the germination rates indicated by the 3-5 separate Rag Dolls to derive a more reliable overall germination rate.

Note: A germination rate of at least 80% is generally considered acceptable. If the germination rate is 60-80%, remember when procuring seed that more than usual will have to be nursed to compensate for non-germinating seeds. If the germination rate is lower than 60%, the rice should probably not be used for seed (unless there is no other seed available, or unless it is of an uncommon variety which the farmer especially wants to multiply).

Caution: If a seed sample has an unacceptable germination rate, do not encourage a farmer to eat it unless you and s/he are certain that the seed has not been treated with pesticide.

III. Soaking and Incubating Seed

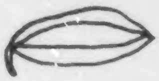
Rice seed should be soaked in clean water and then incubated prior to sowing on seedbeds or directly into tilled soil. Soaking and incubation ensure that by the time the seeds come into contact with the soil they will already have germinated. Pre-germination encourages rapid, even growth and minimizes the danger of seed being washed away (since the emerging radicle quickly burrows down into the soil to anchor the seed in place).

a) Soaking

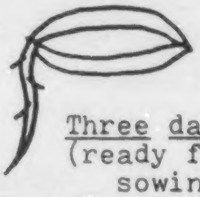
When the seed is ready to be pre-germinated (approximately 3-4 days prior to sowing), a specific-gravity cleaning method should be used to extract all empty and partially-filled grains. Pour the seed into a bucket containing clean water and stir gently. Discard all grains which float to the surface; they contain less endosperm than those which sink and will tend to give rise to weak seedlings. (Note: many farmers will be reluctant to discard what will seem to them to be perfectly good seed. As a demonstration, encourage the farmer to sow the floating seed separately from the rest. The two stands of seedlings should show a marked difference in terms of germination rate and seedling vitality.) When the floating grains have been removed, soak the remaining seed in clean water for 24 hours. Soaking ensures that enough water will penetrate through the husk to cause germination in the embryo.

b) Incubation

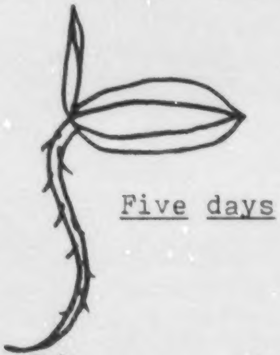
After the seed has soaked 24 hours, drain off the standing water and transfer the wet seed into a burlap sack (if a sack is unavailable, use a basket lined with leaves Make sure the sack (or basket) is filled only very loosely, to permit expansion of the seeds during incubation. Incubate the seed in a warm, shady place for approximately three days, making sure to moisten the sack several times each day. Mix the seed periodically by hand, since toward the center of the sack the germination process will generate considerable heat. Turn the sack daily to discourage the emerging radicles from growing down (they'll try to). When the radicles have attained a length of approximately ½", sow the seeds. Avoid letting the radicles grow longer, as they will penetrate the walls of the sack and/or intertwine. When handling germinated seed, always remember that the newly-emerged radicles are extremely sensitive and succomb easily to drought stress, extreme temperature, and/or rough handling.



Two days



Three days
(ready for
sowing)



Five days

IV. Calculating Seed Requirements

There exists no exact formula applicable to all situations for calculating the amount of seed needed to plant a given area. Several important variables affect seed rice calculations, and they should be taken into account in the case of each individual farmer.

The most significant variables include:

- size of the individual grains
  The size of the individual seed grains can vary enormously from one variety of rice to the next. Thus, a 10-lb. sample of a small-grained variety may contain twice as many actual grains as a 10-lb. sample of a large-grained variety (so that a farmer will have to sow only half as much seed by weight of a small-grained variety to produce the same number of seedlings).
- germination rate of the seed sample
  The germination rate must be taken into account whenever seed requirements are calculated, since even the most careful calculations will yield an incorrect figure if only a portion of the seed ends up germinating. (To cite an extreme example, if the Rag Doll Test indicates a germination rate of only 50%, then the farmer must nurse twice as much rice as usual to compensate for half the seed not germinating.)
- farmer's planting practices
  Differences in planting practices cannot be overlooked during seed requirement calculations. A farmer who plants 2-3 seedlings/hill at a wide spacing will make a small number of seedlings go a long way, whereas a farmer who plants 8-10 seedlings/hill at a close spacing will require more rice. Remember also that different varieties may require different spacings -- this, too, will affect seed requirements.
- presence of inert matter in the seed
  Since farmers sometimes work with seed produced locally under less than ideal conditions, they occasionally must use seed containing large amounts of empty grains, chaff, weed seeds, and grit. Extraneous substances such as these must be taken into account whenever seed requirements are calculated. A farmer accustomed to sowing 20 lbs. of high-quality seed will experience a seedling shortage if he fails to recognize that the 20 lbs. of inferior seed he nursed this year in fact contained 2 lbs. of chaff and grit (hence only 18 lbs. of actual seed).

Because of these and other variables, there exists no universal formula for calculating seed rice requirements. Perhaps the simplest and most effective approach to the problem of calculating seed requirements is to conduct a small experiment with each farmer to determine requirements on an individual basis. Begin by encouraging each farmer to sow a small amount of seed -- perhaps 5-15 lbs. Assist the farmer in all stages of seed selection and preparation, and at the time of transplanting offer advice about proper spacing of the seedlings. Then measure the area the farmer was able to plant with a known quantity of seedlings. By extrapolating, you should be able to determine the seed requirements for the entire farm. Record the information for future reference.

Note: Sometimes it will be necessary to calculate seed rice requirements far in advance of actual planting -- for example, if seed for an entire farming region is being ordered in bulk months in advance. Under those circumstances, a useful "ball-park" figure to work with is 1 bushel seed/acre of swamp (for transplanted rice). This rate will tend to be a bit generous, but it is always best to play it safe when estimating seed requirements. Leftover seed can usually be put to good use, whereas a shortage of seed could prove disastrous should additional supplies be unavailable.

CHAPTER 5

METHODS OF RAISING SEEDLINGS

Introduction

Rice which is to be transplanted into lowland puddled soil must first be nursed on seedbeds. The main reason for nursing rice is simple: to give the seedlings a substantial head start on weeds. Three types of nurseries are used in Sierra Leone -- the wet bed nursery, the dry bed nursery, and the dapog. Each type has advantages and disadvantages, and you will probably end up using different nursing methods depending on the situation. Always keep in mind that it is really very easy to raise healthy seedlings if you are prepared to take enough time to do the job properly. Success in raising healthy rice seedlings depends mainly on constant supervision of the seedbeds and proper management.

Outline of Contents

I. The Wet Bed Nursery
II. The Dry Bed Nursery
III. The Dapog Nursery

I. The Wet Bed Nursery

The wet bed method of raising rice seedlings is the most popular worldwide. Although wet bed nursing is not traditional in Sierra Leone, extension agents have been able to introduce the use of wet bed nurseries with fair success.

The nursing of rice seedlings by the wet bed method is carried out on raised beds within the swamp. Select a fertile, level plot with good water control. Soil preparation should always be very thorough. At least one plowing and a careful puddling are necessary to loosen the soil, as well as to facilitate the decomposition of organic matter. The addition of organic material to plots designated as nursery areas can help ensure seedling vitality, provided it is added early enough to decompose completely.

After soil preparation is completed, peg out the nursery beds with bush poles and string. The beds should be approximately one meter (1m) wide. The relatively narrow width ensures that any area within the bed can easily be reached from either side. Leave alleyways of approximately 40cm between the beds for use later as irrigation channels. Scoop soil from the alleyways by hoe or by hand to construct the beds, which eventually should be raised 10cm above the original surface of the plot. Work through the raised soil with your fingers, breaking up clumps and removing sticks, roots, and stones (this will facilitate uprooting of the seedlings later on). Finally, smooth the surface of the bed, using a board or your flattened hand.

Broadcast pre-germinated seed on the beds, being sure to achieve an even distribution. It is very important not to space the seeds too close, as they will crowd each other out when they begin to grow. An application rate of five (5) pounds /10m bed gives excellent results. When the seeds have been sown, smooth over them with your hands to cover them with a thin layer of soil. This will help protect them against heavy rain or birds. In some cases it will also be necessary to cover the newly-sown beds with palm fronds, banana leaves, grass, or brush.

It is extremely important to keep the beds moist at all times. Although water is usually not a problem with the wet bed, make sure the farmer checks the nursery at least twice a day. If it is not raining every day, moisten the beds morning and evening by splashing water up from the irrigation channels between the beds.

Seedlings in the wet bed nursery can be attacked by insects, although pest infestation is generally not a big problem (if it is, encourage the farmer to make subsequent beds toward the center of the swamp, away from the brushy peripheries where insects breed). If it becomes necessary to resort to the use of a chemical pesticide, do not spray until the seedlings are at least five days old.

The seedlings should be ready for transplanting from 14 days onwards, depending on the variety and the conditions. Younger seedlings are always preferable, as they establish themselves more quickly. The "fourth leaf" stage is generally regarded as optimal. Remember to flood the beds completely beforehand (submerge the soil, not the rice) to minimize damage to the seedlings. Uproot seedlings by holding a few at a time between thumb and forefinger at the base of the culm and pulling sideways. Always handle seedlings with extreme care. Seedlings which are handled gently during uprooting and transporting recover much more quickly when transplanted than those which are crushed, bruised, or allowed to dry out.

Advantages of the wet bed nursery:

- situated right in the swamp
- irrigation water readily available
- seedlings grow rapidly
- seedlings easy to uproot
- minimal disease and pest problems
- excellent for dry season crops

II. The Dry Bed Nursery

Most traditional swamp farmers in Sierra Leone use a form of dry bed nursery. However, almost invariably the beds are constructed hastily, without proper tillage of the soil, and the resulting seedlings tend to be of poor quality. Don't be misled into thinking that dry bed nurseries cannot produce healthy seedlings; under proper management, dry bed nurseries can produce excellent seedlings.

Select a level or gently sloping area near a convenient water source. The hillsides immediately adjacent to a swamp generally make excellent locations for dry bed nurseries. Plow and harrow the soil twice to obtain a fine till. At least 10-15cm of topsoil must be opened up and well pulverized. Addition of decomposed organic matter and/or partially burned rice straw or rice husks will help in keeping the soil aerated and will make it easier to uproot the seedlings.

Peg out the beds in the same manner as wet beds. Scoop soil from the alleyways, using a hoe or shovel. Level the beds and crush any remaining clods by hand or with a stick.

Broadcast the pre-germinated seed just as you would on a wet bed. The application rate should be similar -- five (5) pounds/10m bed is good. Be careful to cover the seeds completely with a thin layer of soil. If heavy rains or birds threaten, cover the beds with fronds or leaves.

The beds should be watered thoroughly immediately after planting and twice every day thereafter. Soak the beds well (to near saturation). If irrigation water is available, water can be sent along the channels and splashed onto the beds; otherwise, water must be carried in by hand. It is impossible to overemphasize the importance of constantly watering dry bed nurseries. Seedlings growing on wet beds can usually absorb sufficient water from below the surface, but dry bed seedlings are totally dependent on rain and hand watering. If the beds dry out for even one day, the growth of the seedlings may be seriously impaired. Do not encourage a farmer to construct dry bed nurseries unless he can be depended on to water them regularly.

Dry bed seedlings will not grow as fast as wet bed seedlings. Seedlings on the dry bed should be ready for transplanting from 21 days onwards. Water the beds to saturation before uprooting to make sure the soil is moist and loose.

Advantages of the dry bed nursery:

- seedlings develop excellent roots
- seedlings easy to uproot
- beds can be made near the farmer's house

III. The Dapog Nursery

The dapog method of raising seedlings originated in the Philippines and is now fairly common in South and Southeast Asia. It is practiced only rarely in Sierra Leone, but it can prove extremely useful in certain situations.

The dapog nursery is constructed for the raising of seedlings without any soil whatsoever. Rice seeds contain sufficient food in the endosperm to permit the young seedling to grow for up to 14 days without receiving any outside nutrients except air, water, and sunlight. Consequently, it is possible to nurse seedlings without actually sowing them in soil.

The dapog nursery can be located anywhere convenient, as long as it is near a reliable water supply. It is usually a good idea to locate dapog nurseries where they can be watched at all times, since they require constant watering and are very susceptible to bird (including chicken) attack. Construct a raised earthern bed roughly one meter square -- the exact shape isn't too important -- and cover it with green banana leaves, or better yet plastic sheeting. Keep the surface of the bed as level as possible, but construct a low raised border to hold the seeds in place after they have been sown and to prevent water from escaping.

Soak and pre-germinate the seed as with the other types of nursery. Pre-germinate a little more seed than usual, because dapog seedlings are quite small when transplanted and difficult to separate; almost inevitably, the farmer will need more of them. Spread the seed in a solid, even layer on the dapog to a depth of approximately 2cm (5-6 seeds thick). Gently sprinkle water over the seeds, taking care not to dislodge them. As the seeds expand during the next few days, press them firmly in place with a board to keep them compacted.

Keep the seeds moist at all times! Without the insulation of a layer of soil, they will dry out very quickly if they are not watered constantly. From about the third day, keep the bed continuously flooded with a thin layer of water.

Regardless of the duration of the variety, dapog-raised seedlings will be ready for transplanting after 9-14 days -- by then the food material contained in the endosperm will have been exhausted, and the seedlings will quickly begin to die off. On the day of transplanting, simply roll up the entire seedling mass (the roots will have matted together to form a sort of rug), throw it over your shoulder, and head for the swamp.

Advantages of the dapog nursery:

- fastest method of raising seedlings
- small nursing area
- situated near farmer's house
- excellent for replacing small quantities of seedlings destroyed by pests
- dapog seedlings recover fast from transplanting because they are not uprooted

CHAPTER 6

METHODS OF STAND ESTABLISHMENT

Introduction

Two methods of stand establishment -- broadcast sowing and transplanting -- are widely practiced in Sierra Leone. This chapter describes both methods and includes summaries of the advantages and disadvantages of each.

Outline of Contents

I. Broadcast Sowing
II. Transplanting

I. Broadcast Sowing

a) Traditional:

Most traditional upland farms in Sierra Leone are sown by broadcasting of ungerminated or germinated seed at the beginning of the rainy season. Seed is scattered by hand at a rate of 80-120kg/ha in soil that has been burned over, cleared, and turned with the native hoe. Usually kitchen crops are mixed in with the rice -- beans, millet, sorghum, tomatoes, corn, okra, sesame, pumpkin, and watermelon are the preferred varieties. The seed is covered by hoe, rake, or spike-tooth harrow. Traditional broadcast sowing is fast and labor-saving, making it particularly well suited to large upland farms. However, traditional broadcast sowing has several marked disadvantages:

- germination rates are often uneven, due to the reliance on rain
- heavy rains can dislodge and wash away seeds, resulting in uneven seedling stands
- seeds are exposed to rat and bird attack
- broadcast seedlings do not compete favorably with weeds
- broadcast seedlings are difficult to weed

b) Improved (Direct Seeding):

In areas where irrigation water is plentiful and easily controlled, direct seeding is extensively used with excellent results. The availablity of water is essential because relatively deep water discourages the growth of grassy weeds. Effective water control ensures that the plots can be drained during the seedling establishment phase.

Two methods of direct seeding are most common: broadcasting directly onto soil that has been prepared thoroughly by plowing and several harrowings, or broadcasting onto standing water (usually from airplanes). Ungerminated or pregerminated seed may be used. The main advantage of improved direct seeding is the low labor cost. The several operations of nursing -- preparing seedbeds, watering, uprooting, and transporting of seedlings -- are completely eliminated. In areas in which labor costs are high, direct seeding can cut production costs significantly. Nevertheless, there are various disadvantages:

- exposure to rats and birds
- weed control is difficult without the use of herbicides

II. Transplanting

a) Hand Transplanting:

Hand transplanting is the most widely practiced method of stand establishment in small-scale, labor-intensive (wet) farming systems throughout the world. Seedlings are nursed in seedbeds and then uprooted for transplanting into lowland puddled soil. The major advantage of transplanting is that the seedlings gain a significant head start over weeds. However, transplanted seedlings tend to grow more slowly than direct-seeded plants because of the root damage suffered during uprooting. Furthermore, hand transplanting is extremely labor-intensive.

Hand transplanting is done either randomly or in rows. Random transplanting, traditional in some parts of Africa and most of Asia, is significantly faster, but the distance between seedlings is not uniform, and no definite aligning pattern is followed. Consequently, randomly-transplanted stands are often uneven, difficult to weed (the use of mechanical row weeders can be ruled out), and difficult to walk around in (e.g. for purposes of broadcasting fertilizer).
Straight row transplanting is done with the use of planting guides (usually a rope knotted at regular intervals, or a planting stick). Straight row planting is time-consuming, but it offers several advantages: optimum spacing is possible, the row weeder can be used, and the stand of plants is easy to walk around in during fertilizer and/or pesticide application.

Transplanted seedlings should not be planted too deep (½"-1" is best), since tillering is discouraged when the lowermost internodes become completely buried. Never thrust seedlings deep into the soil in order to make them stand upright. For best results, barely cover the roots -- the seedlings will right themselves within a day or two, and in the long run they will tiller more vigorously and yield better.

Plant spacing is an important factor and will vary depending on variety, soil fertility, and season of planting. Generally, rice plants are spaced more widely in the wet than in the dry season because in the wet season they tend to grow more profuse leaves and tillers, thus increasing mutual shading. As a general rule, encourage the farmer to plant 3-4 seedlings/hill (except with very low-tillering varieties, which should be planted at a rate of 5-6 seedlings/hill). Space the hills 8"X8" during the wet season, 6"X6" during the dry season. *But be prepared to modify these general recommendations to fit particular situations.*

Note: It is sometimes difficult to decide whether or not to advise a farmer to plant in rows. In theory row planting is preferable to random planting, but in certain situations the extra time required will not always yield better results (e.g. if the farmer does not own a row weeder and will not be walking around in the rice to fertilize). Generally farmers will be reluctant to spend the extra time to plant in rows, and the extension agent must be careful not to alienate them by a rigid insistence that things be done "by the book." Often the best approach is to experiment: offer to help plant a few plots in rows, and then let the individual farmers decide whether or not the additional labor investment pays off in terms of a more uniform, easily-weeded, and higher-yielding stand of plants.

b) *Broadling*:

Broadling is a method of stand establishment practiced in parts of Asia where rice paddies are extremely boggy, making it difficult to walk in them. Nursed seedlings are thrown randomly into the puddled soil from the edges of the paddies. Much practice is required before uniform stands can be achieved on a consistent basis. The seedlings establish themselves quickly, since the roots do not get buried deep in the soil. Although broadling can be effective in some very specialized farming eco-systems, the technique requires smaller plots than are found ordinarily.

CHAPTER 7

LAND PREPARATION

Introduction

The yield of a crop of rice is dependent upon many obvious factors: irrigation, fertilization, weeding, pest and disease control. One of the less obvious but equally important factors is land preparation. Because proper land preparation promotes a good environment for seed/soil contact (which will promote rapid crop growth while reducing competition from weeds), it is imperative that land preparation be thorough and timely. This chapter describes and justifies the steps necessary to prepare lowland soil for a successful growing season.

Outline of Contents

I. Brushing and Clearing
II. Repairing Water Control Structures
III. Plowings and Puddling
IV. Methods of Plowing

I. Brushing and Clearing

Land preparation in inland valley swamps begins with a thorough brushing and clearing. Encourage the farmer to begin with the larger stumps and bushes, since grasses and other weeds grow back very quickly and are best left until just before the first plowing. Bushes and tree limbs should not be left to overhang the edges of the paddies. Rice does not grow well in the shade, and insects thrive in cool, moist areas. The initial brushing and clearing should be completed about one month before planting.

II. Repairing Water Control Structures

Next, clean and repair all water control structures -- dikes, irrigation gutters, drains, and sluice gates. Remove weeds that have grown in the channels and dig out accumulated silt and clay. The flow of water through the channels is impeded by weeds and sediment, and their capacity is greatly reduced. Repair dikes that may have eroded, paying particular attention to the headbund and peripheral (irrigation) gutters. Check all sluice gates for signs of wear; if any threaten to wash out, repair them now. Remember: it is always easier to make repairs and alterations to the water control system before you plant.

III. Plowings and Puddling

After the water control structures have been cleaned and repaired, plowing may begin. Plowing is done in inland valley swamps for several reasons:

- Weed Control (weeds are destroyed and prevented initially from competing with rice seedlings)
- Incorporation of Organic Matter (weeds and crop residues such as straw and stubble are incorporated into the soil, where they become converted into plant nutrients through decay)
- Transformation of Surface Soil into a Puddle (for ease in transplanting)
- Establishment of a Reduced Zone (increases the availability of some nutrients by maximizing contact between rice root hairs and soil particles)
- Levelling (during plowing the soil can be moved around until the plots are level, thus improving water control)
- Formation of a Plow Pan (repeated plowing to a certain depth will create an impervious hard layer, or plow pan, which will reduce water losses and mineral losses through leaching)

To be most effective, plowing must be done thoroughly and timed properly. In inland valley swamps, the ideal schedule calls for two plowings and one puddling. Timing these operations correctly is very important.

1) First Plowing

The first plowing, or deep plowing, should be completed 2-3 weeks before transplanting begins. There are several reasons for such an early start:

- to protect seedlings against the adverse effects of harmful substances generated by decomposing organic materials
- to allow seedlings to utilize the nitrogen-rich ammonium (NH_4) released during the decomposition process
- to spread out the work load for the farmer (thorough plowing is very hard work and is best done a little bit at a time)

Flood the plot for several days before plowing to soften the soil and make the work easier. On the day of plowing, drain off excess water. Using a hoe or shovel, turn the soil to a depth of 15-20cm (6"-8"). Begin near the edges of the plot (so you can repair the bunds if necessary) and work toward the center. Keep the plot flooded after the first plowing until transplanting. If the plot is allowed to dry out, 20-700kg of valuable nitrogen could be lost into the air through a process known as denitrification depending on the soil, its previous cropping history and other factors. Note: Many farmers will at first be reluctant to plow 2-3 weeks in advance of transplanting. The traditional practice in many areas is to wait until the seedlings are nursed and almost ready to plant before starting to plow. Encourage farmers to complete the first plowing before nursing their rice. The 2-3 week lead time will give the organic matter sufficient time to decompose, and the toxic substances released during organic matter decomposition will dissipate before the seedlings are planted.

2) Second Plowing

The second plowing should take place 7-10 days after the first plowing. Break up the softened clumps of soil and incorporate straw, stubble, and weeds that may have germinated. Remove large roots that will not decompose, as well as large stones. Lower the water level in the plot during the second plowing to reveal high spots which will need to be levelled. Re-check the water control system and make minor adjustments as needed.

3) Puddling

Puddling should take place 7-10 days after the second plowing and one day before transplanting. Puddling is usually done with bare feet (and draft animals, in areas where they occur). Bush poles are often used to help maintain balance and to break up remaining soil clumps. Puddling further incorporates germinating weeds, facilitates levelling, and breaks down the soil structure into a soupy mud suitable for transplanting. If a basal application of fertilizer is intended, broadcast the fertilizer just before puddling so that it will be well mixed into the soil. After puddling, the soil will be ready for transplanting.

IV. Methods of Plowing

Plowing may be accomplished in several ways:

- plowing by tractor is generally not suited for inland valley swamps because tractors cannot move easily from plot to plot without destroying water control structures. Furthermore, in flooded soils tractors often are simply too heavy. Initial cost and operating costs are high.

- plowing by roto-tiller (2-5 horsepower) is gaining acceptance in many parts of the world, despite high initial cost and maintenance problems. In broad swamps with large plots, the roto-tiller can be extremely effective and economical. Roto-tillers cannot be used in recently-developed swamps containing many stumps and large roots.

- plowing by animal is extensively practiced with excellent results in most of Asia, but less frequently in Africa (where the use of draft animals is less widespread in general). Most draft animals are able to work only 3-4 hours per day without supplementary feeding, and they require considerable care.

- plowing by hand, though tedious and time-consuming, is the major method of plowing inland valley swamps throughout most of Africa. Hand plowing requires the farmer to spend many hours standing in water and thus facilitates the spread of shistosomiasis.

CHAPTER 8

PLANT NUTRIENTS AND THEIR EFFECT ON GROWTH

Introduction

The growth of the rice plant in any medium (soil, sand, water) depends on the availability of sunlight, water, and various chemical elements. Sixteen elements are recognized as essential in rice nutrition: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, copper, boron, zinc, molybdenum, chloride. Among these, carbon, hydrogen, and oxygen are absorbed directly out of the air and water; the rest must be present in the soil.

Three elements, the so-called primary elements -- nitrogen, phosphorus, and potassium -- are ingested by the rice plant in unusually large quantities and are therefore particularly important in producing a high yield. This chapter provides a brief, non-technical outline of the role of nitrogen, phosphorus, and potassium in the growth of the rice plant.

Outline of Contents

I. Nitrogen
II. Phosphorus
III. Potassium

Note: In considering the effects of individual elements, the relative amounts of other elements present is important. For example, nitrogen alone produces certain effects, but the effects may be quite different if there is a proper balance between nitrogen, phosphorus, potassium, and other elements. The chemical form in which a nutrient element is present in the soil is also important, since the availability of a nutrient to the plant varies with the roots' ability to extract the nutrient element from the chemical compound in which it occurs.

I. Nitrogen

Rice grown under high management requires large amounts of nitrogen (N). One crop consumes approximately 20-25kg of nitrogen for every ton of yield, making nitrogen the single most important rice nutrient. Nitrogen's fundamental importance as a primary nutrient element is augmented by the fact that many improved rice varieties cultivated around the world have been bred to show a marked response to the application of nitrogenous fertilizers.

Nitrogen increases the vigor and enhances the growth of the rice plant. When absorbed during the vegetative phase, nitrogen:

- helps synthesize the chlorophyl necessary for photosynthesis (as evidenced by a marked "greening" of the leaves)
- promotes rapid leaf, stem, and root growth (as evidenced by an increase in the height, size, and number of tillers, as well as an increase in the size of leaves)
- speeds growth, thus enabling seedlings to grow fast enough to avoid many seedling blights

When absorbed during the reproductive and ripening phases, nitrogen:

- promotes development of the panicle (as evidenced by an increase in the number of spikelets)
- stimulates nutrient absorption and assimilation (as evidenced by an increase in size and number of filled grains)
- increases the protein content of the grains, thus improving the quality of the crop

Nitrogen deficiency in rice can be recognized by:

- yellowish color of the leaves, particularly of younger leaves
- small size of plants
- low number of tillers
- straightness, stiffness of upper leaves

II. Phosphorus

Like all cereal grains, rice requires a considerable amount of phosphorus (P) for vigorous growth and high yield. Although in general response to phosphorus in irrigated rice is less marked than response to nitrogen, phosphorus is nonetheless a very important nutrient -- one crop consumes approximately 15kg of phosphorus for every ton of yield.

Phosphorus is particularly important to the rice seedling during the time it is recovering from transplanting shock. Phosphorus greatly stimulates root development in the young plant, thus increasing its ability to absorb nutrients from the soil.

When absorbed during the vegetative phase, phosphorus:

- increases the number of root hairs, thus facilitating the uptake of other nutrients (enables the seedling to recover rapidly from transplanting shock)
- stimulates extensive root growth, thus increasing the plant's resistance to drought
- promotes tillering by facilitating nitrogen absorption
- promotes early flowering and ripening (can be exploited to offset the effects of late planting)

During the reproductive phase, the phosphorus intake of rice decreases considerably.

When absorbed during the ripening phase, phosphorus:

- increases the protein content of the grains, thus improving the food value of the crop
- invigorates the germination power of the seed (as evidenced by an increase in the germination rate of the seed produced)

Phosphorus deficiency in rice can be recognized by:

- small size of plants
- short, underdeveloped root systems
- low number of tillers
- bluish-green color of the leaves
- purple color of the lower part of the culms (Note: some traditional varieties have naturally purple culms.)

III. Potassium

Because of the presence of potassium (K) in most irrigation water, the response of rice to potassium is often not as marked as the responses to nitrogen and/or phosphorus, except in unusual situations (e.g. when certain toxicities are offset by potassium). Nevertheless, potassium should not be overlooked as an important nutrient element, since each crop requires approximately 15kg of potassium for every ton of yield.

When absorbed during the vegetative phase, potassium:

- strengthens cell walls, thus making the plant physically stronger and enabling it to withstand the adverse effects of bad weather
- increases the plant's resistance to penetration by disease organisms

When absorbed during the reproductive and ripening phases, potassium:

- increases the plant's resistance to diseases affecting the panicle and grains
- increases the protein content of the grains, thus improving the quality of the crop
- increases the size and weight of the grains

Potassium deficiency in rice can be recognized by:

- deep, dark color of the leaves (spreading from the tips)
- irregular dead spots on the leaves and panicles
- droopiness of leaves, resulting in reduced photosynthesis and consequent slower growth
- unusual susceptibility to disease and pest attack

CHAPTER 9

FERTILIZER SOURCES AND MANAGEMENT

Introduction

Many rice varieties, particularly the high-yielding improved varieties currently being introduced into many traditional farming systems throughout the world, respond markedly to fertilization. When used in conjunction with good management practices (thorough land preparation, controlled irrigation, timely weeding) fertilizers can increase yields many times over. On the other hand, if used improperly fertilizers can damage crops, waste money, or possibly lead to a dependence on scarce chemical inputs. In many developing areas fertilizers are still unknown or poorly understood, and the extension agent represents the farmer's only source of information about safe, economical, and effective fertilization practices.

This chapter describes the most common sources of fertilizer and outlines a recommended application schedule for irrigated rice. Included are practical suggestions for effective handling, application, and storage of chemical fertilizers.

Outline of Contents

I. Fertilizer Sources
II. Fertilizer Management
III. Fertilizer Calculations

I. Fertilizer Sources

A. Organic Fertilizers

.Organic fertilizers are decomposed remains of plants and animals. In the natural ecosystem, elements absorbed from the soil by living organisms are returned to the soil through decay and decomposition following the death of the organisms. Organic fertilizers traditionally have provided all of the nutrients in shifting agriculture systems where periods of cultivation alternate with fallow periods (during which the natural regenerative process restores organic fertilizers to the soil). Organic fertilizers also have traditionally provided most nutrients to swamp farming systems, since swamps serve as natural catchments for organically derived nutrients which wash down off the surrounding uplands.

The introduction of improved rice varieties into a traditional swamp farming system tends to create a situation where the nutrient demands of the crop outstrip the natural ability of the ecosystem to replenish its organic resources. Although knowledgable swamp farmers can exploit the natural regenerative properties of many so-called "waste" products to help maintain soil fertility (e.g. by incorporating organic material back into the soil), and although they can replenish nutrients by planting nitrogen-fixing legumes during part of the year, repeated high yields will inevitably extract greater amounts of some nutrients -- particularly nitrogen, phosphorus, and potassium -- than can rapidly be returned to the soil through the use of organic fertilizers or alternate cropping practices. Thus, the swamp farmer is faced with a decision. Either s/he opts for a balanced farming system which will be able to sustain medium yields over a long period with minimal chemical inputs. Or s/he elects to try for the highest possible yields -- which in most cases means relying on inorganic fertilizers.

B. *Inorganic Fertilizers*

Inorganic fertilizers are chemical compounds (either synthesized or natural) which are added to the soil to improve fertility. The most important characteristics of inorganic fertilizers are that they can be extremely *economical* (i.e. they can vastly increase yields and can result in significant profits), and they are *fast-acting* (since the nutrients they contain are immediately available to the crop and do not have to be processed by microbes in the soil).

Depending on their chemical composition, inorganic fertilizers may contain only one nutrient or several:

Single-element fertilizers contain only one of the primary nutrient elements (N,P, or K)

Incomplete fertilizers contain two of the three primary nutrient elements (N and P, N and K, or P and K)

Complete fertilizers contain all three of the primary nutrient elements (N,P, and K)

It is important to remember that inorganic fertilizers always consist of the nutrient element(s) *bonded to an inert* "*carrier*". Consequently, the total weight of the fertilizer does not correspond exactly to the weight of the nutrient it contains; the weight of the nutrient comprises only a part of the total fertilizer weight and varies according to the chemical composition of the fertilizer. For example: one 100 lb bag of ammonium sulphate (20% N) contains 20 lbs nitrogen and 80 lbs of inert material, while one 100 lb bag of urea (45% N) contains 45 lbs nitrogen and 55 lbs of inert material. In terms of its ability to supply nitrogen, urea is therefore more than twice as "strong" as ammonium sulphate because it contains more than twice as much nitrogen by weight.

Listed below are the fertilizers most commonly used in Sierra Leone (fill in current prices):

1) Single-element fertilizers

Ammonium sulphate (20% N) Price:
Urea (45% N) Price:

Single superphosphate (18% P_2O_5) Price:
Basic Slag (14.5% P_2O_5) Price:

Muriate of Potash (60% K_2O) Price:
Sulphate of Potash (50% K_2O) Price:

2) Incomplete fertilizers

N-P-K 20-20-0 (20% N, 20% P_2O_5, 0% K_2O) Price:
N-P-K 0-20-20 (0% N, 20% P_2O_5, 20% K_2O) Price:

3) Complete fertilizers

N-P-K 15-15-15 (15% N, 15% P_2O_5, 15% K_2O) Price:

Notes on fertilizer storage:

Great care should be taken in handling, transporting, and storing chemical fertilizers. Although most inorganic fertilizers are fairly inert when kept dry, many undergo drastic chemical changes when exposed to rain, or even moisture in the air. The resulting gases and liquids not only carry off valuable nutrients, but they can cause considerable corrosive damage to cement floors and walls, metal tools, motorcycles, etc.

It is best to store chemical fertilizers by themselves in a dry, well ventilated room. Be sure to keep the bags off the floor (use wooden pallets to elevate them), and stack them so that air can circulate between the bags. Avoid storing food, seed rice, or pesticides nearby.

Take the time to construct a proper fertilizer store. Improper storage can present a safety hazard and decrease the power of the fertilizer.

II. Fertilizer Management

There is no single recommendation for rice fertilization which will fit all situations. Fertilizer applications will vary considerably, depending on crop requirements, the availability of fertilizers, the financial resources of the farmer, and most importantly, the ability of the farmer to follow application schedules (some of which can be quite complicated).

Tests and field experience have shown that the application of 40 kg/ha (36 lbs/acre) each of nitrogen, phosphorus, and potassium gives optimum results under most local conditions. (Important: that's 40 kg/ha of nutrient, not of fertilizer.) 40 kg/ha is the generally recommended application rate. Of course many farmers will be either unwilling or unable to purchase this amount of fertilizer, and they will end up fertilizing at a much lower rate (or not at all). Decreasing the amount of fertilizer will result in more modest yields, but keep in mind that any amount of fertilizer, no matter how small, will help. If a farmer needs to fertilize but can afford only one bag of N-P-K 15-15-15 per acre, don't necessarily discourage him/her. If applied properly, even this relatively small amount of fertilizer will affect favorable results.

Timing Fertilizer Applications

For optimum results, fertilizer should be applied to the soil at three points in the crop cycle:

1) The Basal Application

Just prior to transplanting, fertilizer should be broadcast and puddled into the soil to ensure an abundance of nutrients during the critical seedling establishment phase. The basal application facilitates the plant's rapid recovery from the shock of transplanting. If possible, *all phosphorus* should be applied basally, since root development is crucial at this time.

2) *First Top Dressing*

When the seedlings have fully recovered from the shock of transplanting and have entered into the active tillering stage (approximately two weeks after transplanting for most varieties), fertilizer should be broadcast and puddled into the soil. This operation can be combined with the first weeding. The first top dressing ensures rapid vegetative growth, promotes tillering, and helps strengthen the plants against disease attack. *Nitrogen* and *potassium* should be applied with the first top dressing.

3) *Second Top Dressing*

Immediately after panicle initiation (the date will vary according to the duration of the variety), fertilizer should once again be broadcast and puddled into the soil. The second top dressing ensures complete grain filling, increases the size and weight of the grains, and improves the quality of the crop by increasing the protein content. *Nitrogen* and *potassium* should be applied with the second top dressing.

An ideal fertilization schedule thus might look something like this:

Day of transplanting - *Basal Application*

40 kg/ha phosphorus

Active tillering - *First Top Dressing*

20 kg/ha nitrogen
20 kg/ha potassium

Panicle initiation - *Second Top Dressing*

20 kg/ha nitrogen
20 kg/ha potassium

HOWEVER: it is possible that many farmers will have neither the means nor the ability to adhere closely to such a schedule. Often you will find yourself working with smaller amounts of fertilizer, or with only one incomplete or complete fertilizer instead of several single-element fertilizers. Expect to adjust this application schedule to the requirements of each situation -- "go with the flow." You may want to devise a separate schedule for each farmer; do the best you can to get the nutrients to the rice when they will be needed most.

Some tips on applying fertilizers:

- It is sometimes difficult to broadcast small amounts of fertilizer over a relatively large area. Since uneven distribution of nutrients is ineffecient and in some cases actually harmful to the rice, remember that fertilizer can always be stretched by the addition of an inert filler such as dirt or sand.

- Never broadcast nitrogenous fertilizers (ammonium sulphate, urea, N-P-K) onto standing water. Upon contact with water, the ammonium ions are converted to ammonia gas, and much nitrogen is lost into the air. Broadcast all top dressings onto drained plots and then puddle in the fertilizer by hand before re-flooding.

- Be sure that water does not flow out of recently fertilized plots. Water carries off nutrients!

- Always be aware of safety considerations. Try to avoid fertilizing in swamps from which water is used for drinking, washing, or laundering, unless an alternative water source is available. Helping dig a well or construct a water system is one of the most beneficial secondary projects you can undertake with the farmers in your community.

Additional thoughts on fertilizers:

Although it is tempting for all of us as agriculture extension agents to attempt to sell farmers on the use of fertilizers, we must always be careful not to present a distorted picture of nothing but higher yields. The potential benefits of fertilizer use should be described only in the context of the potential costs: possible dependency and possible safety hazard. Above all, if farmers are to be taught to use chemical fertilizers, they should be taught to use them efficiently, safely, and in moderation. It is unwise to encourage a heavy reliance on inorganic fertilizers in an era when the spiralling price of petroleum products (and many fertilizers are petroleum by-products) threatens to make widespread use of fertilizers uneconomical. When working with fertilizers, try always to remain aware of the fine line between the use of fertilizers to enhance yields and total reliance on them.

III. Fertilizer Calculations

There are a number of variables to consider when calculating the amount of fertilizer to be applied to a given area. These include:

- the percentage of nutrient contained in the fertilizer being used
- the desired rate of application
- the size of the area to be fertilized

In addition, because most farmers do not have access to an accurate scale or balance, it will often be necessary to devise a simple means of converting amounts of fertilizer into a common volume measurement (e.g., an 8 ounce cup).

The extension worker can attack the problem of calculating fertilizer for farmers in a number of ways, depending on the degree of accuracy desired. Described below are two approaches to the problem which have proven useful in the past in Sierra Leone.

1) The Rough-and-Ready Method

The simplest method of determining a farmer's fertilizer needs is to calculate how many bags of fertilizer will be needed for the entire swamp and then to divide the swamp and the fertilizer into smaller units at the time of application to ensure a relatively even distribution. First, measure the entire swamp and calculate its area. Practiced field workers can sometimes make an approximate guess at a swamp's area, but make sure the practice at measuring precedes the guessing. Choose the fertilizer you will use -- or in most cases, assess what is available. Using the recommended rate of 40 kg/ha, calculate the amount of fertilizer required with this formula:

$$W = \frac{A \times R}{F} \qquad \text{where}$$

W = weight of the fertilizer to be applied (this is what you are calculating)

A = area to be fertilized (hectares or acres)

R = desired rate of application (in this case the recommended rate, or 40 kg/ha)

F = percentage of nutrient contained in the fertilizer

Example:

You have measured a farmer's swamp to be approximately 1.5 ha. How many bags of urea will be required to fertilize the entire swamp with nitrogen at the recommended rate?

Using the formula $W = \frac{A \times R}{P}$, where:

$W = ?$
$A = 1.5$ ha
$R = 40$ kg/ha
$P = 45\%$ or $.45$ (determined from the fertilizer chart)

then

$$W = \frac{1.5 \text{ ha} \times 40 \text{ kg/ha}}{.45}$$

$$= \frac{60 \text{ kg}}{.45}$$

$$= 133.33 \text{ kg}$$

$$= \text{approximately } 130 \text{ kg urea}$$

Each bag of urea weighs 50 kg; therefore, to convert 130 kg into bags, divide 130 kg by the weight of one bag:

$$130 \text{ kg} = \frac{130 \text{ kg}}{50 \text{ kg}} = 2.6 \text{ bags}$$

The problem now is to ensure that the 2.6 bags of urea get distributed evenly over the 1.5 ha swamp. Try dividing the swamp into ten small sections. Then get together with the farmer and, using a local unit of measure, divide the fertilizer into ten equal piles. Make certain that the farmer understands exactly what you are doing together, because in the future s/he will be doing the same operation without your assistance. Above all, keep things simple.

2) The Fertilizer Tables

Developed swamps are divided into plots smaller than a hectare, acre, or even half acre. A more exact method of calculating fertilizer applications is by the individual plot. This method lends itself well to swamps in which management practices have reached a more sophisticated level, or in which only a few plots are planted at a time.

Then simply multiply this figure -- the multiple of the standard area -- by the figure appearing in column 6 (since we are working in English measurements here) to determine the cups of basic slag needed:

2.5 x 4.8 = 12 cups of basic slag

Now suppose the farmer checks the storeroom and discovers that there is no more basic slag. But there is a quantity of another phosphoric fertilizer -- single superphosphate. How many cups will be needed to fertilize the plot at the recommended rate with single superphosphate?

Since you have already measured the area of the plot and calculated the multiple of the standard area -- and recorded this information on a map of the swamp -- a quick reference to the fertilizer tables will enable you to determine how many cups of single superphosphate will be needed.

Multiply 2.5 (the multiple of the standard area) by the figure appearing in column 6 opposite the line marked "single superphosphate":

2.5 x 7.4 = 18.5 cups of single superphosphate

The use of the fertilizer tables requires a detailed area survey and a fair amount of math. However, the survey need be performed only once, since the measurements and plot area calculations can be preserved for future reference on a sketch map. The same map can later be used for a number of different purposes: fertilizer calculations, seed requirement calculations, pesticide calculations, and yield comparison.

How to use the tables

The columns in the table are as follows:

column 1 - name of the fertilizer

column 2 - number of 8 ounce cups (filled to overflowing) in one 50 kg bag

column 3 - weight of the fertilizer in one cup in grams/(ounces)

column 4 - weight of the nutrient in one cup in grams/(ounces)

column 5 - number of cups needed to fertilize 100 m^2 at the recommended rate of 40 kg/ha

column 6 - number of cups needed to fertilize 1000 f^2 at the recommended rate of 36 lbs/acre

If the area of the plot to be fertilized is known, columns 5 and 6 will enable you to calculate rapidly the amount of fertilizer necessary to fertilize at the recommended rate. Simply divide the known area of the plot by 100 m^2 (if you are using metric measurements) or by 1000 f^2 (if you are using English measurements) to get a multiple of the standard area used in column 5 and column 6. (Be careful to keep to the same system, metric or English, throughout each calculation.) Then multiply this figure -- the multiple of the standard area -- by the figure appearing in either column 5 or column 6 (whichever is appropriate for the units of measurement you are using) to determine the number of cups of fertilizer needed to fertilize at the recommended rate.

Example:

You have measured a plot to equal 2500 f^2. You want to make a basal application of phosphorus using basic slag as the source of P. The desired rate of application is 36 lbs/acre. How many 8 ounce cups of fertilizer are needed?

First, divide the plot area (2500 f^2) by 1000 f^2 to get a multiple of the standard area:

$$\frac{2500\ f^2}{1000\ f^2} = 2.5$$

FERTILIZER TABLES

Note: one cup = 8 ounces

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
FERTILIZER TYPE	Number of cups/ 50kg bag	Weight of fert./cup grms (oz)	Weight of nutr./cup grms (oz)	# cups/ 100 sq.m @40kg/ha	# cups/ 1000 sq.f @40lbs/a
UREA (45% Nitrogen)	190	263 (9)	120 (3.8)	3.4	3.5
AMMONIUM SULPHATE (18% Nitrogen)	147	340 (12)	61 (2)	6.5	6.8
SINGLE SUPER-PHOSPHATE (18-20% P_2O_5)	160	312 (11)	60 (2)	7.1	7.4
BASIC SLAG (14.5 P_2O_5)	103	485 (17)	70 (2.3)	5.6	5.9
MURIATE OF POTASH (60% K_2O)	145	345 (12)	207 (7.3)	1.9	2.0
SULPHATE OF POTASH (50% K_2O)	125	400 (14)	200 (6.5)	2.0	2.1
N-P-K 15-15-15 (15% each N,P,K)	150	333 (12)	50 (1.6)	8.0	8.2
N-P-K 20-20-0 (20% N,P - 0%K)	160	312 (11)	62 (2.0)	6.4	6.7

Conversion rates used:

1 kg = 2.2 lbs
1 lb = .453 kg
1 oz = 31 g
1 g = .032 oz

1 ha = 10000m^2 = 2.47 a
1 a = 43560sq. feet
= .405 ha

CHAPTER 10

INSECT PESTS OF RICE

Introduction

In Sierra Leone, as in most regions in the developing world where irrigated rice is grown, insect pests can be a major problem. Tropical conditions favor the year-round proliferation of insects, and double-cropping practices provide a steady habitat for feeding and breeding. In order to take preventative measures against insect pests, the farmer must be able to recognize crop damage and identify which insect pest is responsible. This chapter provides a brief introduction to the major insect pests of rice in Sierra Leone, grouped according to the type of crop damage they inflict.

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I. Stem Borers
II. Leaf Cutters/Leaf Feeders
III. Leaf Scrapers
IV. Root Feeders
V. Grain Suckers

I. Stem Borers

a) Crop Damage

Rice stem borers are one of the most destructive types of insect pests of rice, occuring regularly and afflicting plants from seedling to maturity. Stem borers are the larval stage of any one of several species of winged insects which lay their eggs on the leaves or stems of the rice plant. When the egg hatches, the larva emerges, bores into the inside of the culm, and feeds on the interior of the stem. While feeding, the borer cuts off the growing part of the plant from the base, causing the tiller to die. Farmers generally cannot see the borer unless they cut the stem open. The presence of stem borers is most often determined by signs of crop damage.

To determine the presence of stem borers, look for the following signs:

- dead hearts (young tillers which have dried up and died after borers have cut off the growing part from inside)
- white heads (empty, whitish panicles resulting from stem borer attack after panicle initiation had already occurred)
- holes in the stems (indicate where the borer entered the stem)
- presence of adult insects

b) Species Most Common in Sierra Leone

Name	Larva	Adult
Striped stem borer	light brown larva with 5 thin stripes length to 17mm	dirty brown moth (dark spots on wings)
Pink stem borer	pink larva with a dark head; segmented length to 25mm	dark brown moth (white band across wings)
White stem borer	creamy white larva length to 17mm	white moth
Yellow stem borer	yellowish larva length to 17mm	straw-colored moth (pointed head)
Diopsis, or Stalk-eyed fly	white larva with sets of "feet" length to 25mm	rust-colored bug with eyes at the end of stalks

II. Leaf Cutters/Leaf Feeders

a) Crop Damage

Leaf cutters and leaf feeders include a wide variety of different species of insects. Although they can attack at any point in the crop cycle, damage is generally most heavy during the seedling and tillering stages, when the leaf tissues are tender and succulent.

To determine the presence of leaf cutters/leaf feeders, look for the following signs:

- irregular holes eaten into the leaf surface
- skeletonizing of leaf blades (i.e. leaves eaten down to the midribs)

- cut-off leaf tips
- pieces of leaves floating in the water (also cases -- see note on caseworm below)
- presence of insects (many species of leaf cutters/leaf feeders are easily observed, e.g. caterpillars, grasshoppers)

b) Species Most Common in Sierra Leone:

Name	Larva	Adult
Caterpillars	various sizes and markings	butterflies and moths
Grasshoppers		various sizes and markings
Army worms	black worms length to 35mm (appear periodically in mass concentrations)	hairy, brick-red moth
Caseworm*	pale green larva length to 25mm	dirty white moth (nocturnal)

*Note on caseworm:

Caseworm is a pest specific to irrigated rice and represents the single most destructive insect pest of rice in Sierra Leone (with the possible exception of the occasional invasions of army worms). Caseworm infestation can be extremely widespread in newly transplanted rice, and crop loss can approach 100% if control measures are not taken. The worms feed on the leaves and stems and in many cases cut off the leaf tips, resulting in a "mowed" appearance of the rice.

The worm is semi-aquatic in habit and needs to live in water in order to draw in oxygen through its gills. It carries a water supply with it by living inside a water-filled "case" which it constructs by cutting off a leaf segment and rolling itself up inside. This case serves as a portable environment. It also doubles as a boat: when the caseworm wants to move to another rice plant, it drops into the water and floats inside the case to a new source of food. Each caseworm attacks several plants in this fashion and constructs many cases before it is fully grown.
(for control measures, see next chapter)

III. Leaf Scrapers

a) Crop Damage

Leaf scrapers are generally present in moderate numbers in Sierra Leone and habitually cause relatively minor damage. However, in certain instances they can represent a really serious threat to a crop. Leaf scraper damage occurs most frequently during the seedling and early tillering stages, while the vegetative tissue is still succulent and easily attacked. As the name implies, leaf scrapers damage plants by scraping off the chlorophyl-containing layers of the leaves.

To determine the presence of leaf scrapers, look for the following signs:

- *pale, colorless areas* on the leaf surface (where the chlorophyl-containing tissues have been scraped off)
- *presence of insects*

b) Species Most Common in Sierra Leone:

Name	Larva	Adult
Grasshoppers		various sizes and markings
Epilachna, or Lady-bird beetle		orange, black-spotted beetle oval, length 5-6mm

IV. Root Feeders

a) Crop Damage

Root feeders attack the roots of the rice plant and feed on the living tissues, causing eitherstunting or death. Damage generally proves serious only during the seedling establishment and early tillering stages, when the plant's root system is just beginning to develop extensively. Root feeders breathe air and consequently are found only in plots which are not flooded. Often root feeders make their homes inside the bunds, venturing forth into the plots only to feed.

To determine the presence of root feeders, look for the following signs:

- *dead seedlings* (no other visible damage)
- *tunnel tracks* in the soil leading to affected plants
- *presence of insects*

b) Species Most Common in Sierra Leone:

Name	Larva	Adult
Mole Cricket		brown or charcoal-gray cricket (length to 35mm) front feet developed for tunnelling

V. Grain Suckers

a) Crop Damage

Grain suckers have been known to cause severe crop loss in Sierra Leone, especially in areas where continuous cropping occurs. Often the damage caused by grain suckers is not immediately apparent, since many empty grains are not discovered until harvesting has taken place and winnowing begins. Grain suckers attack the rice plant during the milk stage of the ripening phase and suck out the liquid contents of the grain, leaving only the empty husk.

To determine the presence of grain suckers, look for the following signs:

- empty grains with tiny holes bored through the husk
- erect panicles (indicating empty grains that have been sucked dry)
- presence of insects

b) Species Most Common in Sierra Leone:

Name	Nymph	Adult
Rice bug	tiny, green (rice colored) also sucks sap	long, slender insect greenish-brown length 14-17mm

CHAPTER 11

PEST PREVENTION

Introduction

Irrigated rice must be protected against serious damage from permanent or sporadic pests. In many developing regions, the tendency is to rely on control of pests (through chemical pesticides), rather than on prevention of pests (through management practices). It is up to the extension agent to make the farmer aware that pest control in its broadest sense includes everything that makes life difficult for the pest, kills it, discourages it from reproducing, or prevents it from spreading. This chapter describes some of the management practices which can help prevent pest infestation from reaching the stage where the farmer will be forced to resort to chemical control.

Outline of Contents

I. Educating the Farmer
II. Preventative Practices/Insects
III. Preventative Practices/Birds
IV. Preventative Practices/Rats

I. Educating the Farmer

The key to effective pest prevention lies in a complete and accurate understanding of the pest, its life cycle and habits. Although most farmers will usually be able to identify the pest causing damage to their crops, often they lack a detailed knowledge of the relationship between the pest and the rice growth cycle. This is hardly surprising, since most pest activity occurs at night, or in places in which it is difficult to observe (e.g. inside the stem of the plant).

Perhaps the most important contribution the extension agent can make toward pest prevention is to educate the farmer about the life cycle and habits of the pest. Teach the farmer to look for signs of crop damage. Point out as many pests as you are able to identify, and explain as much as you know about their life cycles. Ask questions which will start the farmer thinking regularly about pests.

II. Preventative Practices/Insects

With one or two exceptions, it is difficult to eliminate insect pests completely simply with management practices -- but there is no question that preventative practices can have a significant effect in controlling or reducing insect populations. And since crop damage occurs in direct proportion to insect population, it is important to know which management practices will help keep down the numbers of harmful insects. Preventative practices which have been effective in Sierra Leone include:

a) Flooding

After the harvest, many species of insect pests enter into the pupating, or resting stage. Flooding the plots immediately after harvest can drown many pupating insects, especially stem borers. Flooding also effectively controls air-breathing insects, such as the mole cricket.

b) Draining

Draining the plots represents an easy, inexpensive, and effective control against caseworm. Encourage the farmer to drain the affected plot(s) dry for 7-10 days to prevent the spread of caseworm. (Note: be sure not to drain the water out of one plot and into another, since this will merely result in the spread of the infestation.)

c) Burning

Burning off straw and stubble after the harvest drives away any remaining insects, kills pupating insects in the soil, and helps control disease as well.

d) Plowing

Removal of paddy stubbles and wild grasses after harvest by plowing them under will minimize the next generation of insect pests by killing larvae hibernating in the soil and eliminating a ratoon crop (which serves as a host environment for rice-specific pests).

e) Brushing Bunds and Peripheries

Many species of insect pest emerge from the plots during certain farming operations (e.g. brushing, burning, plowing) and seek refuge in the weeds growing on the bunds and along the edges of the swamp. Brushing the bunds and peripheries deprives many insects of a valuable habitat and can significantly reduce their numbers.

f) Crop Rotation

Crop rotation can be extremely effective against certain insects, especially rice bugs. In a heavily pest-infested area, encourage as many farmers as possible to plant a rice pest resistant crop (e.g. groundnuts or cowpeas). If deprived of a rice environment, many rice-specific insects will move elsewhere or die.

g) Uniformity of Planting

If sufficient labor is available, encourage the farmer to plant the entire crop at one time. Since the entire crop will subsequently undergrow the same growth stages at the same time, certain pests which attack only during certain growth stages (e.g. rice bug) will have a very short attack "window."

h) Host Plant Resistance

No rice variety has been found to be immune from insect attack, but certain varieties clearly are more susceptible to attack by certain insects. Teach the farmer to be aware of such susceptibilities (most farmers will in turn be able to teach you about such things). Advise against the continued use of varieties which local insects seem to prefer.

III. Preventative Practices/Birds

Birds represent the single greatest pest hazard to rice farmers in Sierra Leone. Bird attack during the final stages of grain ripening can cause losses of up to 90% in unguarded stands -- in a matter of days. Most farmers are well aware of the bird problem and rely on traditional methods of prevention and control. These include bird-scaring apparati (constructed of sticks, vines, tin cans filled with pebbles, rags, etc...), slings, and snares.

Note: Some farmers attempt to poison birds by baiting them with rice treated with pesticide. Needless to say, this practice is extremely dangerous, all the more so because people have been known to eat the birds killed by the poisoned bait. Always discourage this practice, which in any case affects only a few birds.

IV. Preventative Practices/Rats

Rats also can pose a major pest problem -- and they can be extremely difficult to control. Two types of rat are common in Sierra Leone. The cutting grass is a large nocturnal animal (weighing up to 40 lbs) which causes extensive damage to rice by feeding on the bases of the culms. Although many farmers believe that cutting grass will not cross broad irrigation channels or enter into flooded plots, the animal in fact is an excellent swimmer. Maintaining 6"-8" of standing water on the plots will slightly discourage feeding, but the only effective control is to fence off the swamp and deny the animal entry, or hunt it.

Another rice pest is the smaller field rat (actually several different species). These 8"-10" animals live in nests constructed inside the bunds and attack the rice during all growth stages. They are extremely difficult to control as they make their homes inside the swamp itself. The most effective way to control their numbers is to tear apart the bunds and destroy the nests.

CHAPTER 12

PESTICIDE SAFETY AND AGRO-CHEMICAL USE

Introduction

The use of chemical pesticides in developing countries is subject to considerable controversy. Pests destroy up to one third of the world's food crop every year. An even greater percentage is lost in developing countries, where safe and effective pesticide use is rare.

Part of your job as an agriculture extension agent will be to teach farmers and agro-technicians how to control insect damage through a combination of preventive management practices and pesticide use. This chapter provides a brief introduction to the basic safety measures which should always accompany the use of chemical pesticides.

Outline of Contents

I. Pesticide Toxicity
II. Safety Guidelines
III. Symptoms of Poisoning
IV. First Aid Measures

I. Pesticide Toxicity

Pesticides are useful for keeping farm animals healthy and for killing insects, weeds, and plant diseases. When used improperly they can hurt or kill other things in the environment, including you or the people you work with.

All pesticides are toxic, ranging from the most dangerous (Category I) to the least dangerous (Category IV). The LD_{50} rating (LD refers to lethal dose) indicates the amount of pesticide that will kill 50% of test animals (male rats) in terms of milligrams of pesticide per kilogram of body weight. If the LD_{50} of a rat poison is 148, then 148 mg of the poison will kill one of every two rats that weigh 1kg each. LD_{50} values provide a fairly good measure of the relative toxicities of pesticides to humans. Each type of pesticide is generally assigned two LD_{50} values, for dermal contact (contact through the skin) and for oral contact (ingestion through the mouth).

The LD_{50} rating gives no information on the cumulative effect of repeated exposure. Organophosphates such as Phosdrin (mevinphos) and Parathion interfere with the transmission of nerve impulses by inhibiting the enzyme cholinesterase, and because the body cannot rid itself of these poisons, their effects can be cumulative. Several small, non-lethal doses can add up to a lethal dose.

Even relatively "safe" pesticides such as Malathion or Sevin can cause severe poisoning if enough of the pesticide is ingested or spilled on the skin, particularly in concentrated form.

Toxicity of Common Pesticides

(LD_{50} values in mg/kg)

Pesticide	Use*	Oral	Dermal
Category I - Most Dangerous			
Phosdrin (Mevinphos)	I	6	4.7
Category II - Dangerous			
Bidrin	I	21	43
Category III - Less Dangerous			
BHC	I	600	-
Chlordane	I	335	690
2, 4-D	H	650	-
Dithane D-14	F	395	1000
Paraquat (Gramoxone)	H	120	480
Nemagon	N	173	1420
Vapona (Dichlorvos)	I	90	107
Category IV - Least Dangerous			
Captan	F	9000	-
Daconil (Bravo)	F	10000	10000
Malathion	I	1375	4444
Sevin (Carbarryl)	I	850	4000

*F = fungicide
I = insecticide
H = herbicide
N = nematocide

II. Safety Guidelines

1) Laws and Regulations

Make sure you are using, storing, and disposing of pesticides in accordance with the laws and regulations of the country in which you live and work.

2) Read and Understand the Label

All persons using pesticides should understand the directions and precautions on the label before opening the container. The label should state the name of the pesticide, amount of active ingredient, uses, suggested dosages, precautions, and first aid instructions. If the label is vague or unclear, try to obtain a descriptive pamphlet. Never buy or use pesticides that come in unmarked sacks or bottles. Any U.S. labels which lack the above listed information should be reported, with a copy of the label if possible, to the Peace Corps Information Collection and Exchange (ICE), Washington, D.C. 20525. All this information is required on the label by law, and any failures to comply will be brought to the attention of the U.S. Environmental Protection Agency.

3) Protect Yourself

The proper use of safety equipment and protective clothing is essential in handling and applying chemicals. Rubber gloves and boots, trousers (outside of boots), long-sleeved shirt, waterproof hat and coat, and proper measuring equipment are the minimum requirements when pesticides are applied. In many instances a respirator is necessary as well. Thoroughly wash all clothing before wearing it again. Avoid handling chemicals when wearing leather shoes, since chemicals are easily absorbed by leather and are very difficult to remove.

4) Category I and Category II Pesticides

When working with farmers, avoid using Category I and Category II pesticides, particularly Bidrin, Phosdrin, Phosphamidon, and Trithion. If you or other pesticide experts ever find it necessary to use pesticides in either Category I or Category II, be sure to wear the required protective clothing, regardless of how uncomfortable it may get. Insist that farmers who use these pesticides (almost invariably they should not be) are trained to use protective clothing.

5) Exposure to Pesticides

In handling any pesticide, avoid repeated or prolonged contact with the skin, or inhalation of dust or spray. Clothing should be changed and hands and face washed before eating, smoking, or going to the bathroom. Wash immediately with detergent and clean water when your hands, skin, or any part of the body become contaminated or exposed.

6) Safe Working Area

Prepare pesticide solutions in a well-lit, well-ventilated place, preferably outside. Keep livestock, pets, and people out of the mixing area. Wear proper protective clothing and read the label before opening the container. Mix the solution carefully to avoid accidental splashing. If a spill occurs, soak up the spill with sawdust or soil and bury the contaminated material in a hole at least 50cm deep in an isolated place where water supplies will not be affected. Cover the material with dirt.

7) Windy Days

Never spray or dust on windy days. Do not spray pesticide if people or animals are nearby. Avoid treating crops while bees or other pollinators are active in the field. Do not apply pesticides if apiaries (beehives) are near enough to be affected adversely; notify the beekeeper so he can move the hives if necessary.

8) Protecting Passersby

Do not permit unprotected passersby to enter treated fields until the spray has dried or the dust has settled.

9) Pesticide Storage

Store pesticides in a dry, well-ventilated place out of the reach of children and away from food and animals. Store pesticides in the original, labelled containers, tightly sealed to prevent the release of harmful vapors.

10) Pesticide Containers

Make sure that pesticide containers are never put to any other use. Burn all empty bags, as well as cardboard and plastic containers. Do this in an isolated place, when the wind will not cause contaminated smoke to drift among homes, people, livestock, or crops. Keep well out of the smoke. Bury the ashes 50cm deep in an isolated place where water supplies will not be contaminated. Break all glass containers, crush or punch holes in metal cans, and burn and bury as above.

11) Water Sources

Do not contaminate streams, swamps, or other water sources either during application or when cleaning equipment. Rinse water and leftover spray mixture should be poured into a hole in the ground, never into a stream or swamp.

III. Symptoms of Poisoning

Symptoms of pesticide poisoning vary depending on the chemical group of the pesticide and the severity of the exposure. Repeated exposure to small amounts of some pesticides can cause sudden severe illness. Poisoning caused by synthetic organic pesticides (organophosphates, chlorinated hydrocarbons, carbamates) may cause one or more of the following symptoms:

Mild poisoning:

- irritation of the skin, eyes, nose, throat
- weakness, dizziness
- nausea, stomach cramps or diarrhea
- excessive sweating and salivation
- chest discomfort
- blurred vision
- numbness of hands and feet

Moderate poisoning:

- difficulty talking and breathing
- poor muscle coordination
- rapid pulse, flushed skin
- constriction of pupils
- muscle twitching
- increased severity of earlier symptoms

Severe poisoning:

- unconsciousness
- severe constriction of pupils
- convulsions
- inability to breathe
- secretions from the mouth and nose
- death

Symptoms may be delayed several hours following exposure. Appearance of some of the symptoms does not necessarily indicate poisoning -- other kinds of sickness may cause similar symptoms. Always consult a physician to be certain.

IV. First Aid Measures

1) If breathing has stopped, give artificial respiration immediately.

2) Get the victim to a doctor or hospital as soon as possible. Take the pesticide label along for the doctor's information. Do not carry the pesticide container in the passenger space of a car or truck.

3) If the pesticide has been swallowed, check the label to see if the victim should be made to vomit. Vomiting can be induced by giving the victim one tablespoon salt dissolved in half a glass of warm water. To avoid dehydration, however, the preferred method is to stick a finger or spoon down the victim's throat. Position the victim face down or kneeling forward to avoid choking and/or strangulation. After vomiting has been induced, make the victim lie down and keep warm. Never induce vomiting in a person who is unconscious or having convulsions.

4) If a pesticide gets on the skin, immediately remove all contaminated clothing and wash the affected skin with detergent and water. Don't forget hair and fingernails.

5) If a pesticide gets in the eyes, wash immediately and for at least five continuous minutes with generous amounts of water. Have them checked by a doctor.

6) If a pesticide has been inhaled, get the victim to fresh air immediately and have them lie down. Loosen clothing and keep the victim warm and quiet. If breathing stops, begin artificial respiration. Summon medical assistance immediately.

(SEE NEXT PAGE FOR INSTRUCTIONS ABOUT ARTIFICIAL RESPIRATION)

ARTIFICIAL RESPIRATION

1) Place the victim face up.

2) Remove all foreign matter from the victim's mouth with your fingers.

3) Lift up under the neck and tilt the head as far back as possible, until the chin points up. This position is important to keep the air passage open.

4) For an adult victim, pinch the nostrils shut and place your mouth tightly over the victim's mouth. For a child victim, place your mouth over the mouth and nose. A hankerchief should be placed between your lips and the victim's to prevent your coming into contact with the pesticide.

5) Take a breath and exhale into the victim until you see the victim's chest rise. Use shallower breaths for children.

6) Remove your mouth and release the victim's nostrils. Listen for the sound of air coming out.

7) Repeat - every 5 seconds for adults
   - every 3 seconds for children

8) Bulging of the stomach may make breathing more difficult. Turn the head of the victim to one side and press gently on the stomach. This will force air out of the stomach but may cause vomiting.

9) If vomiting occurs, quickly turn the victim on their side, wipe out the mouth, and then reposition them.

10) Continue artificial respiration until the victim begins to breathe unassisted, or until a doctor pronounces the victim dead, or until the joints stiffen.

CHAPTER 13

PESTICIDE CALIBRATION

Introduction

Most pesticide application in Sierra Leone is done with backpack, pump-type sprayers. The main function of a sprayer is to break the liquid pesticide solution into droplets of effective size and distribute them uniformly over the surface or space to be protected. Another function is to regulate the amount of pesticide to avoid excessive application (which might prove harmful, wasteful, and costly) or insufficient application (which would fail to give effective control). This chapter describes the common formulations of locally available pesticides and explains step by step how to dilute them to obtain the desired concentration for field application.

Outline of Contents

I. Pesticide Formulations
II. Pesticides Available in Sierra Leone
III. Sprayer Calibration
IV. Pesticide Dilution

I. Pesticide Formulations

Most common pesticides are available commercially in one or more of the following forms: dust, wettable powder, emulsifiable concentrate, or granules.

1. Dusts

Dusts are widely used in agriculture, especially where it is difficult to obtain large volumes of water for diluting sprays. The toxicant is mixed or diluted with a carrier, such as talc, and mechanically blended by the manufacturer. A low concentration of the toxicant is helpful in making an even application. Dusts are applied dry with hand dusters, ground dusting equipment, or aerial equipment, and are not intended to

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be mixed with water or oil. In order to avoid drift it is best to use dusts when there is little or no wind, and the crops are wet from dew or rain. Because they contain a minimum of solvents and no emulsifiers, dusts are least likely to harm delicate plants.

2. Emulsifiable Concentrates

An emulsifiable concentrate is an oil-based liquid compound containing a high concentration of the toxicant. These concentrates contain emulsifiers (agents which facilitate mixing with water), as well as wetting and sticking agents to make them readily emulsifiable in water and liable to adhere to plants. Before use, they must be diluted in water. They can be applied as ground sprays, or with aerial spray equipment.

3. Wettable Powders

Wettable powders, although similar in appearance to dusts, contain a wetting agent which permits them to become dispersed and suspended when mixed with water and applied as a liquid spray. Since powders do not dissolve but rather stay in suspension, spray tanks must be equipped with agitators to keep the particles in suspension. Wettable powders contain no oil or solvent, and they are consequently safer than some emulsifiable concentrates for use on plants with delicate foliage.

4. Granules

Granular pesticide formulations consist of free-flowing grains or inert materials either mixed or impregnated with a toxicant. Granules offer these advantages: they do not need any further mixing or diluting; they present no drift problem during application; and they can be broadcast directly by hand without expensive equipment (since almost invariably they are made up of compounds showing low toxicity to humans).

All of these different forms of pesticides have their place in insect control because of differences in weathering properties, uptake characteristics, life cycles of insect pests, and/or growth characteristics of crops.

II. Pesticides Available in Sierra Leone

MALATHION - LD_{50} Values Oral: 1375 Dermal: 4444
Organophosphate (contact insecticide)
Formulation: emulsifiable concentrate, wettable powder
Active Ingredient: 25% or 50%
Use: Insect control in rice, vegetables

GAMMA-BHC - LD_{50} Values Oral: 600 Dermal:
Chlorinated hydrocarbon (systemic insecticide)
Formulation: wettable powder
Active Ingredient: 25%
Use: Insect control in rice, vegetables

PHOSDRIN - LD_{50} Values Oral: 6 Dermal: 4.7
Organophosphate (contact, systemic insecticide)
Formulation: emulsifiable concentrate
Active Ingredient: 24%
Use: Insect control in rice, vegetables
EXTREMELY DANGEROUS - NOT RECOMMENDED

BIDRIN - LD_{50} Values Oral: 21 Dermal: 43
Organophosphate (contact, systemic insecticide)
Formulation: emulsifiable concentrate
Active Ingredient: 24%
Use: Insect control in rice, vegetables
EXTREMELY DANGEROUS - NOT RECOMMENDED

KOCIDE 101 LD_{50} Values Oral: Dermal:
Active Ingredient copper (contact fungicide)
Formulation: wettable powder
Active Ingredient: 54%
Use: Control of black pod disease in cacao

III. Sprayer Calibration

If and when it becomes necessary to apply pesticides, it is likely that application will be made with a pump-type backpack sprayer. These sprayers are relatively inexpensive, simple, and easy to operate. It is important that the extension agent be well versed in the use and calibration (calculation of the rate of spraying) of the backpack sprayer. Even if the extension agent does not actively encourage farmers to apply pesticides, it is quite possible that s/he will be approached by farmers owning their own equipment for instruction in the use of the sprayer. One of the best ways to help decrease pesticide abuse is to provide accurate information about the proper calibration and safe use of spraying equipment.

Before each application of pesticide, it is necessary to calibrate the sprayer to determine the exact rate of spraying. The rate of spraying is the amount of liquid emerging from the sprayer (in normal use) to cover a given area. This differs significantly from the rate of pesticide application, which is the amount of pesticide applied per unit area. The rate of spraying varies according to the physical characteristics of the sprayer and has nothing to do with the properties of the spray itself, but the rate of pesticide application varies according to the rate of spraying and the concentration of the mixture in the tank. (This is an important distinction and should be understood clearly.) Only once the sprayer has been calibrated (to determine the rate of spraying) will it be possible to determine how much pesticide to mix with water in the tank to achieve the desired rate of pesticide application.

The rate of spraying depends on four major factors:

1) Pressure in the spray tank

Keep the pressure in the tank as constant as possible. A pressure regulator or pressure gauge is ideal, but usually these are lacking. Smooth, even pumping will help keep the pressure relatively constant.

2) Size of nozzle orifice

The size of the nozzle orifice regulates the amount of spray passing through the nozzle. The nozzle orifice wears with use and therefore must be recalibrated regularly.

3) Spray swath

The spray swath, or "path" covered by the droplets, varies according to the height at which the tip of the nozzle is held. Keep the swath as constant as possible.

4) Walking speed of sprayperson

Walking speed directly affects the area covered per unit time, which in turn determines the amount of spray applied per unit area. Maintain an even walking speed when spraying, to the extent possible.

When calibrating a sprayer, it is important to keep in mind that the calibration will be valid only for that particular sprayer in that particular swamp with that particular sprayperson, since a change in any one of these variables will afect a change in the rate of spraying.

To calibrate a sprayer, follow this procedure:

1. Prepare sprayer
   a) Rinse supply tank and fill with clean water.
   b) Remove nozzle; check and clean if necessary.
   c) Flush pump, hose, and lance with clean water.
   d) Apply pressure (i.e. pump) and check sprayer for leaks.

2. Determine walking speed of sprayperson
   a) Fill tank with clean water.
   b) In an actual paddy, mark starting point with a stake.
   c) Using your wristwatch, begin 1 minute trial. Walk at a constant and normal speed, carrying the filled sprayer on your back. Pump the sprayer handle with one hand to maintain pressure and direct the nozzle with the other hand to obtain a spray swath of approximately 1m width.
   d) Stop walking at the end of exactly 1 minute and mark the stopping point with a second stake.
   e) Measure the distance between the starting and stopping points. Record the distance in meters. Walking speed can be expressed in terms of m/minute.
   f) Repeat trial at least three times to obtain an average walking speed.

3. Calculate area sprayed in one minute

   If the spray swath was kept at (approximately) 1m, the area sprayed in one minute can be calculated easily using the known walking speed:

   Area sprayed in one minute = spray swath (1m) x walking speed (m/minute). The answer is expressed in terms of m^2/minute.

4. Determine nozzle discharge in one minute

   a) Fill sprayer with clean water and pump sprayer handle to build up pressure.
   b) Dip end of nozzle into a graduated cylinder.
   c) Using your wristwatch, begin 1 minute trial. Open the cut-off valve and spray into the graduated cylinder. Make sure none of the spray escapes.
   d) Cut off the discharge at the end of exactly 1 minute.
   e) Note the volume (in liters) of liquid collected. This is the nozzle discharge, expressed in terms of liters/minute (l/min).
   f) Repeat trial at least three times to obtain an average nozzle discharge.

Now you can easily compute the rate of spraying:

$$\underset{(l/m^2)}{\text{Rate of spraying}} = \frac{\text{nozzle discharge } (l/min)}{\text{area sprayed } (m^2/min)}$$

Since most pesticide application rates are given in terms of l/ha, the rate of spraying should be converted to the same units of measurement:

$$\text{Rate of spraying} = \frac{l}{m^2} \times \frac{10000m^2}{1ha} = \frac{l}{ha}$$

i.e., simply multiply the rate calibrated for $l/m^2 \times 10000$.

IV. Pesticide Dilution

Once the sprayer has been calibrated, it is very easy to calculate the amount of pesticide which must be diluted with water to achieve the desired mixture. Since the rate of spraying has been calibrated in terms of liters (spray)/ha, and since pesticide application rates are given in terms of liters (e.c. of pesticide), the desired ratio of emulsifiable concentrate to water can be determined by simple division:

$$\text{Mixture} = \frac{\text{desired rate of pesticide application (liters e.c./ha)}}{\text{calibrated rate of spraying (liters water/ha)}}$$

$$= \frac{\text{liters emulsifiable concentrate}}{\text{liters water}}$$

CHAPTER 14

DISEASES OF RICE

Introduction

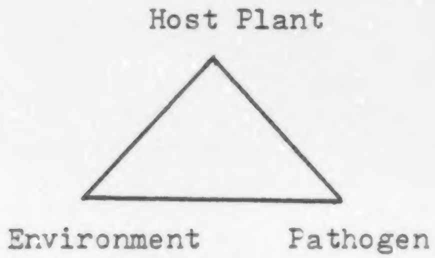
Like many countries in the humid tropics, Sierra Leone has a climate particularly conducive to the development and spread of plant diseases. High humidity, rain, and heavy dew are associated with increased activity of disease-causing organisms. As a result, virtually every crop of rice grown in Sierra Leone is subject to at least mild disease infection. In some instances, infection becomes severe, leading to heavy crop losses. This chapter describes several of the most common diseases of rice found in Sierra Leone and touches upon management practices which may help to prevent them.

Outline of Contents

I. Disease Considerations
II. Diseases Common in Sierra Leone
III. Management for Disease Control

I. Disease Considerations

The three "ingredients" of plant disease are 1) the host plant, 2) the pathogen, or disease organism, and 3) the environment. Taken together, these comprise the components of the so-called disease triangle.



It is important to recognize that the three components are interdependent. Presence of the host plant and the pathogen does not imply occurrence of the disease. The environment plays a crucial role as well: it must be conducive for the two biological systems (the plant and the pathogen) to interact in a way that infection may take place and disease follow. Consequently, disease control can involve manipulation of any one, or all three, of these components.

Disease infection can be divided into stages: 1) entry of the organism into the plant, and 2) spread of the infection through the plant. Pathogens can enter through weak or injured roots, through mechanically or insect-damaged stems or leaves, through weak outer cell walls, through dead tissue, or through succulent and easily bruised leaves.

II. Diseases Common in Sierra Leone

Listed below are several of the diseases of rice occurring most frequently in Sierra Leone in irrigated crops:

1. Blast (including Neck Blast and Leaf Blast)

Pathogen: *Pyricularia oryzae* (fungus)

Infection takes place at any stage of growth. Lesions are typically oval or spindle-shaped, with a grayish center and a brown halo. When several lesions join, the infected leaf appears blighted. Mild infections of blast occur regularly in Sierra Leone. Although in most cases the disease fails to kill the affected plants, farmers should realize that lesions on the leaf surface inhibit the plant's ability to photosynthesize and thus reduce yields. Blast is often associated with nutritional imbalances. Note: some varieties (e.g. CCA) are particularly susceptible to neck blast; crop losses of up to 100% have been recorded in some instances.

2. Brown Spot

Pathogen: *Drechdleria oryzae* (fungus)

Brown spot can affect the crop at any stage of growth and often appears as early as the seedling stage. Brown spot starts as small, circular to oval, dark brown lesions with a light yellow halo around their outer edge. (Brown spot can be distinguished from blast by the absence of a grayish center in the lesions.) Infection can spread to cover the entire leaf surface, particularly in stands of upland rice. The disease is often associated with nutritional deficiency and/or drought stress.

3. Narrow Brown Leaf Spot

Pathogen: *Sphaerulina oryzae* (fungus)

Narrow brown leaf spot resembles brown spot, except that the lesions are shorter and distinctly more linear. Some lesions have slightly broadened centers. They occur most commonly on the upper leaves and often increase in numbers during the latter stages of growth.

4. Sheath Blight

Pathogen: *Rhizoctonia solanii* (fungus)

Initial symptoms of sheath blight infection appear as grayish-green lesions on the leaf sheath between the surface of irrigation water and the leaf blade. Adjoining lesions often merge, weakening the entire stem and causing it to topple and break. The lesions may also extend to the leaf blades, especially among susceptible varieties.

5. False Smut

Pathogen: *Ustinaginoidea virens* (fungus)

Infection by false smut occurs after heading and affects the ripening grains. Infection results in the transformation of the individual grains into greenish spore balls of velvety appearance. The balls are slightly flattened, smooth and yellow, and covered by a membrane. With growth the membrane swells and bursts, exposing the orange content of the ball. Infected grains are rendered inedible.

6. Leaf Scald

Pathogen: *Rhynchosporium oryzae* (fungus)

Leaf scald is quite common on mature leaves. The infection forms oblong or diamond-shaped blotches. These increase into large ellipsoid olive areas which ultimately dry out and turn gray. Often the entire leaf tip succombs to the scald, which can be recognized by its characteristic banded pattern of alternating light and dark grays.

III. Management for Disease Control

Because strong plants and a healthy environment can rule out disease even in the presence of pathogens, it is easy to see why management practices play an important role in combatting plant diseases. Encourage farmers to adopt as many as possible of the following management practices to decrease the incidence of disease in their crops:

a) Selection of Resistant Varieties

As a method of rice disease control, the selection of resistant varieties is often the most practiced method. The reasons are obvious when one considers the simplicity of the practice. It represents the most economical and sensible approach, and it appeals best to farmers because it is cheap, effective, and within the reach of their means and technical skills. Work with farmers to keep track of which varieties seem most disease-free under local conditions and suggest that they be planted exclusively.

b) Balanced Fertilization

Nutritional imbalances -- both deficiencies of nutrients and excesses -- render rice plants much more susceptible to attack by pathogens. Deficiencies result in a general decline in the plant's health, while excesses can cause a sudden growth spurt leading to a weakening of cell walls. Either condition invites attack, as evidenced by the clear relationship between diseases such as blast and brown spot and nutritional imbalances. Balance fertilizer applications (i.e. apply fertilizer in several splits instead of all at once) to minimize the risk of nutrition-related disease.

c) Crop Rotation

Crop rotation can disrupt the life cycle of some pathogens (e.g., fungi) by removing from the environment the necessary host plant. Crop rotation can also discourage multiplication of soil-borne organisms which live among the roots of the rice plant.

d) Burning of Crop Residues

Disease organisms do not die when rice is harvested; they either produce spores which linger on in the paddies to infect subsequent crops, or they seek alternate hosts among nearby weeds. Encourage farmers to burn residues left over after the harvest (chaff, stubble, refuse) to kill disease-causing organisms and to destroy alternate hosts.

CHAPTER 15

WEEDS AND WEED CONTROL

Introduction

Weeds constitute the single greatest cause of crop loss in Sierra Leone. Because their effect on yields tends to be underestimated, their presence is often tolerated. Weeds are defined simply as "plants out of place." This definition may be expanded to include any plants that interfere with the cultivation of desirable plants, that cause economic loss through increased production costs, or that reduce the yield and/or quality of the crop. This chapter describes the nature of weed competition with rice plants, briefly reviews common weed types, and recommends management practices which can help control weeds in rice.

Outline of Contents

I. Weed Competition
II. Common Types of Weeds
III. Management for Weed Control

I. Weed Competition

The most obvious action of a weed is competition with desirable plants. Competition denotes a relationship between the same or different species which leads to the flourishing of one at the expense of the other (or at the expense of both). While weed competition with rice does not normally lead to the death of either species, it almost invariably results in decreased yields in rice. Weeds are known by everyone, but the extent of the problem they pose is not necessarily recognized. Farmers tend to acknowledge the weed problem in their swamps, but the high labor cost of hand weeding (the predominant form of weed control) discourages adequate response.

The precise nature of the competition between weeds and rice depends on the following influences:

a) relative growth stages of rice and weeds

b) nature of stand establishment (transplanting vs. direct seeding)

c) density of planting

d) rice variety (short variety vs. tall, leafy variety)

e) moisture and nutrient availability

In most irrigated swamp farming systems, rice seedlings are transplanted into puddled soil. This practice gives rice a substantial head start on weeds, and competition is minimal initially. However, competition greatly increases as growth progresses. (This is particularly true in stands of direct-seeded rice, since weeds germinating at the same time compete for light and nutrients with the rice seedlings.)

Weed competition generally takes three forms:

1. Competition for Light

Weeds that are shorter than rice throughout all stages of growth compete little or not at all with rice for light. However, weeds that are taller can reduce the light available to rice by as much as 50%. Since sunlight provides the main source of energy utilized by plants for manufacturing food material (through photosynthesis), shading by tall weeds can significantly stunt growth and reduce yields.

2. Competition for Water

Under lowland conditions where water is plentiful, competition between rice and weeds for water is minimal. But whenever there is a shortage of water -- during the dry season in some swamps, and on the uplands generally -- the situation is quite different. If weeds consume a significant portion of the available water supply, processes such as tillering, flowering, and grain filling can be delayed or impeded.

3. Competition for Nutrients

Weeds have a large nutrient requirement. They are voracious feeders and can, if left uncontrolled, absorb more of the soil nutrients than the crop. Increases in fertility brought about through fertilization generally are accompanied by increases in weeds, which can result in larger yield reductions.

Note: In addition to competing with rice for sunlight, water, and nutrients, weeds pose another problem for the swamp farmer. Many weed species act as alternate hosts for insect pests and disease-causing organisms, and the presence of weeds among the crop or along bunds and swamp peripheries can significantly increase crop losses due to insect and/or disease attack.

II. Common Types of Weeds

It is important that the farmer be able to recognize and identify different types of weeds, because effective weed control measures may depend on this knowledge. Four main types of weeds are common in swamp farming systems:

1. Grasses

Grasses are characterized by long, narrow leaves with parallel veins; the leaves arise alternatingly at solid nodes between hollow internodes (similar to rice, except for the absence in grasses of both auricles and ligule). Grasses are generally the most difficult weeds to control because during the early growth stages they are often mistaken for rice seedlings.

2. Sedges

Sedges are similar to grasses, but they have three ranked leaves, triangular solid stems, and closed leaf sheaths. Most sedges are semi-aquatic, preferring moist or flooded soils such as are common in rice paddies, and they are a frequent problem in swamps. Some of the most common sedges have razor-edged leaves and therefore are very difficult to handle.

3. Broad-leaf Weeds

As the name implies, broad-leaf weeds are broad-leaved plants with net veins (as opposed to parallel veins). In lowland ecosystems they can further be distinguished as floating or rooted types. The latter can be a particular problem to the rice farmer, since hand weeding tends to leave behind in the soil root sections which later regenerate. Broad-leaf weeds are commonly found choking water control channels.

4. Algae

Algae comprise a large and diverse group of simple photosynthetic plants. All are aquatic or semi-aquatic. They occur particularly where water is extremely slow-moving or stagnant, and they compete with rice plants chiefly for nutrients.

III. Management for Weed Control

Weeds can be controlled in irrigated rice through the use of management practices, including the application of herbicides. Most weed control in Sierra Leone is affected through non-chemical means, which although labor-intensive can be extremely effective. Management practices for weed control include:

1. Land Preparation

   Thorough land preparation can significantly decrease the incidence of weeds in rice by a) destroying all weeds and weed seeds to provide weed-free conditions at the time of planting, and b)providing a good environment for rapid growth of rice seedlings.

2. Water Management

   Many weeds cannot germinate and/or grow in flooded soils, making water management an extremely effective tool for controlling weeds -- particularly grasses and sedges. When the transplanted seedlings have established themselves (approximately one week after transplanting), completely flood the plot to a depth of 3"-4" to inhibit weed growth. As the rice grows, gradually increase the depth to 6". Important: the soil must be submerged completely and uninterruptedly if flooding is to be effective.

3. Hand Weeding

   Hand weeding, although time consuming and tedious, remains the most important weed control method currently in use in Sierra Leone. When the weeds are large enough to be gripped, they are pulled out of the soil and discarded. Smaller weeds can be hand puddled deep into the soil. The earlier hand weeding is carried out the better, since any delay will enable the weeds to absorb nutrients. A common fallacy among swamp farmers is that small weeds do not affect the rice -- but they certainly do, as a simple weeding demonstration will show.

4. Hand Hoeing

   Hand hoeing is used widely as a method of weed control in several rice-growing countries, particularly where line-planting is practiced. Hand hoeing is faster than hand weeding and works well against creeping perennials.

5. Brushing Bunds/Peripheries

All weeds originate somewhere; many, particularly annual grasses and sedges, reproduce by wind-spread seed. One very effective means of controlling the spread of weed seeds into rice paddies is to brush bunds and swamp peripheries. If brushing is carried out regularly, annual weeds will be prevented from completing their reproductive cycles, and the production of weed seeds will be inhibited.

6. Crop Rotation

Since every crop has its own characteristic weeds, continued cultivation of the same crop in one plot allows these weeds to build up. Rotation of swamp rice with an upland crop (during the dry season) may result in reduced infestations of water-tolerant weeds in the subsequent rice crop(s).

7. Herbicides

Herbicides are chemicals used for killing or for inhibiting the growth of plants. In certain instances they can be used effectively and economically for weed control, but as with any pesticide the use of herbicides poses potential health and environmental problems.

Herbicides are divided into three groups, depending on the time of application:

a) Pre-planting (application before crop is planted)

b) Pre-emergence (application after planting, but prior to emergence of weeds)

c) Post-emergence (application after emergence of weeds)

Herbicides also can be distinguished according to the mode of action:

1) Contact herbicides - kill plant tissues at or very close to point of contact.

2) Systemic herbicides - move within the plant to exert affects away from the point of contact.

3) Selective herbicides - kill or stunt some plant species, with little or no effect on others.

Because of a lack of knowledge about the long-term effects of herbicides in swamp farming systems, their use generally should be discouraged in Sierra Leone among local farmers.

CHAPTER 16

MANAGEMENT OF FLOODED SOILS

Introduction

Under continual flooding, swamp soils develop characteristics which are fundamentally different from those of upland soils. Although it is not essential that the farmer have a complete technical understanding of the differences between the two types of soils, it is important to know about some basic properties of flooded soils so that management practices will be appropriate for local conditions. This chapter describes basic properties of flooded soils and recommends measures that may be adopted to help overcome the sorts of soil problems most often encountered in swamp farming systems. In addition, the problem of iron toxicity is discussed.

Outline of Contents

I. Characteristics of Flooded Soils
II. Management of Problem Soils
III. Iron Toxicity

I. Characteristics of Flooded Soils

Three major changes -- physical, biological, chemical -- occur when a soil is flooded. A brief review of these changes will help lead to a better understanding of soil management practices which will maximize yields in irrigated rice.

1. Physical Changes

Upon flooding, the pore spaces (air spaces) in the soil become saturated with water. As a result, the soil swells, and hard clods soften and break into small aggregates. Puddling completely destroys the remaining structural aggregates (clods and clumps) and transforms the soil into a sludge, or soupy mixture. This slows the drying of the soil, since the exchange of air between the atmosphere and the soil is impeded, and since the water particles are held by soil particles and prevented from percolating downward and escaping.

2. Biological Changes

The absence of soil air (and particularly oxygen) in flooded, puddled soils causes a change in the varieties of microbes, or microscopic organisms which live in the soil. Microbes existing in the absence of oxygen are known as anaerobic microbes, and they tend to be much slower, less efficient decomposers of organic matter than their aerobic cousins. Consequently, the rate of decay of organic matter tends to be slow in flooded soils. Also, the end products produced by anaerobic decomposition differ; some are toxic to rice, particularly those released during the first two weeks after decomposition begins. This can be important in timing organic matter incorporations between plantings: if the farmer plants too early into a flooded plot containing plowed-under stubble and/or chaff, the toxicities produced during normal decomposition may stunt the growth of the rice.

3. Chemical Changes

Flooded soils develop two distinct chemical zones. (see figure below) The upper zone, a thin 1-10mm, absorbs oxygen from the water, turns brown in color, and reacts to nitrogen like an unflooded soil. This zone is called the oxidized zone, in reference to its chemical condition of being oxidized. The lower zone, which extends down as far as the water, is extremely low in available oxygen, turns dark blue or gray in color, and takes on chemical properties quite different from those of the oxidized layer above. This lower zone is known as the reduced zone.

When a soil is flooded, the nitrogen in the incorporated plant (and animal) residues is changed to the ammonium form (NH_4), which is stable under flooded conditions and will later be used by growing rice plants. If the soil is allowed to dry thoroughly (e.g., when it is drained for plowing), a microbacteriological change takes place during which the ammonium form of nitrogen is changed to the nitrate form (NO_3).

When the soil is later re-flooded, part of the nitrogen held in the nitrate form is changed into nitrogen gases (N_2,NO_3) and escapes into the air. Between 20-700kg/ha of nitrogen can be lost through this process, known as denitrification, so it is extremely important to keep the plot thoroughly flooded at all times after initial irrigation has taken place.

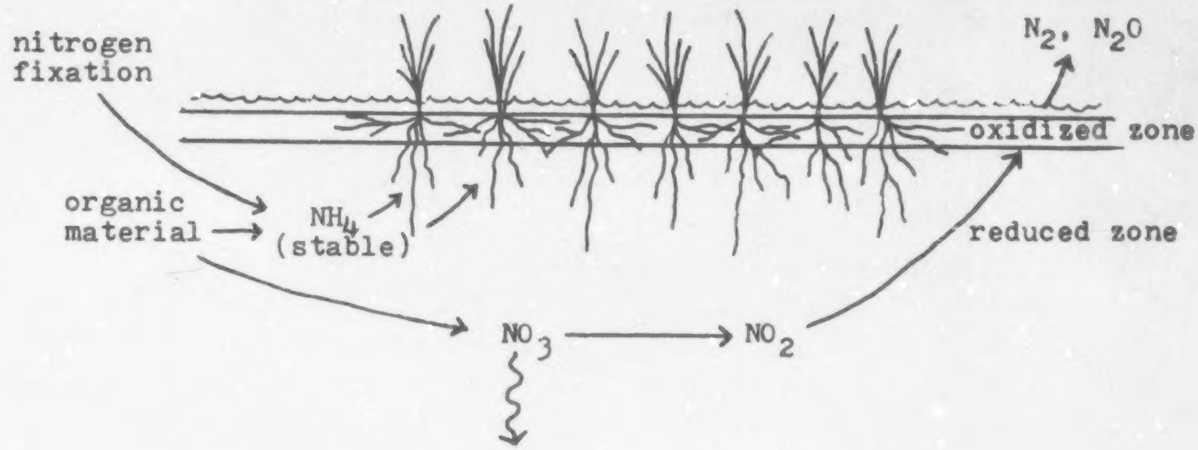


Figure: Flooded Soils and Denitrification

II. Management of Problem Soils

All swamp farming systems are not created equal. Although swamps tend to look the same from the ground, often they vary considerably below the surface. Some swamps are shallow and sandy, others deep and peaty, still others filled with rock or clay deposits. Because soil characteristics significantly affect plant growth, the farmer should know what steps should be taken to minimize soil-related problems.

The key to management of problem soils lies in anticipating potential problems before they occur and taking the steps necessary to head them off. Problem soils can be attacked three ways: 1) through the selection of an appropriate variety, 2) through proper swamp development, and 3) through effective management practices. Never wait until after the crop is in the ground to begin thinking about soil problems, since by then it will be too late to change varieties or modify the water control system.

Always begin thinking about the soil early in the development process. The very first time you visit a farmer's swamp, take the time to dig a few scattered pits to reveal local soil characteristics. Question the farmer about the depth of the topsoil, about the type of underlying material, about the presence of undecomposed organic material, etc. With a little practice, you will learn to identify problem soils long before planting time, and consequently you and the farmer will be able to devise an effective strategy involving development, varietal selection, and crop management.

A. Sandy Soils

Many swamp systems in Sierra Leone are extremely shallow and sandy. The main problem with sandy soils is leaching: water percolates through sand very easily, carrying away nutrients and bringing in toxic materials. Effective water control is difficult, because sandy soils do not retain water well; as a result, drought stress is common among crops grown in sandy swamps. Nutrient deficiencies occur regularly, as evidenced by stunting, yellowing of the leaves, and low tillering.

To treat sandy soils:

1) Development practices

Develop the swamp so as to discourage leaching. There are several ways to slow movement of water through the soil:

- keep the main drain shallow (so it will not "suck" water from the plots).
- dig deep peripheral gutters (to intercept groundwaters percolating down from adjacent hillsides).

2) Varietal Selection

Select a variety which does well under relatively difficult conditions, i.e. a variety which can withstand an irregular water regime, nutrient deficiencies, and soil toxicities.

3) Management Practices

To minimize leaching and the damage it causes:

- keep a constant, slow-moving or non-moving flood on the plots.
- spread out fertilization by applying top dressings in many small splits.

To improve the structure and fertility of the soil, as well as to improve its ability to retain water, incorporate large amounts of organic material before and, if necessary, after the growing season.

B. Peaty Soils

Swamps which remain permanently flooded often contain large amounts of undecomposed organic matter (because the soil never gets a chance to dry, which means that aerobic decomposition never occurs). Peaty soils are characterized by high acidity and the presence of numerous toxic materials, both of which severely affect crop growth. Peaty swamps are easily recognized by matted clumps of undecomposed organic material, noxious gases, and mineral slicks. Rice grown in peaty soil is usually stunted, browning, and low tillering.

To treat peaty soils:

1) Development Practices

When developing the swamp, be sure to dig an effective drain. The main drain should be extremely deep to draw water not only from the surface of the plots, but from beneath the surface as well.

2) Varietal Selection

Select a variety which does well under conditions of high acidity. An iron toxicity-resistant variety is usually a good bet, or a native variety.

3) Management Practices

To enable aerobic decomposition of organic material in the soil:

- continually drain the plots.
- till the topsoil during the dry season to a depth of several feet, if possible (encourage the farmers to construct vegetable mounds).

To prevent incorporation of additional organic material into the soil, burn all grasses, weeds, and crop residues (stubble, chaff, etc.).

C. Clays

Clays have a high natural fertility, but often they resist giving up their nutrients to plant root systems. Furthermore, because of their dense structure (they are composed of extremely small, tightly-packed particles), they tend to be difficult to work. Therefore, improving the structure of clays should be the farmer's primary goal. When the clay is fairly dry (just before it starts to crack), begin tilling to increase aeration. Incorporate large amounts of organic material, and practice crop rotation to help maintain fertility.

III. Iron Toxicity

Iron toxicity is a soil-related condition caused by the presence of too much iron in lowland rice paddies. Occurring in virtually all regions in Sierra Leone, iron toxicity results from a complex set of chemical imbalances (in the soil and in the plant) which in many instances severely inhibits yields. The condition occurs most commonly in sandy areas of swamps adjoining upland slopes, or in peaty areas where drainage is poor.

The symptoms of iron toxicity are numerous and varied, but the most typical indication is a marked bronzing of leaves and stems, generally occurring 4-7 weeks after transplanting. In addition, roots are stunted, coarse, and reddish brown or dark brown in color (a coating of iron oxides reduces root surface and decreases capacity to absorb soil nutrients). Plants are stunted and tiller poorly. In extreme cases, black or brown spots appear on leaves and stems, and leaf edges turn dark brown and roll in toward the midrib.

The causes of iron toxicity are technically complex and hence difficult to describe succinctly. Very simply, the presence in the soil of excessive quantities of iron inhibits nutrient absorption by the plant and leads to severe nutritional imbalances which manifest themselves in the typical symptoms. The intake of phosphorus and potassium is especially inhibited, and it is the relative lack of these two primary nutrients (in conjunction with the relative abundance of nitrogen) which causes many of the symptoms.

Treatment of iron toxicity can take several forms. Swamp development measures which can help prevent development of a situation favorable to iron toxic conditions include deepening peripheral gutters in sandy swamps (to decrease percolation of iron compounds down from the uplands) and improving drainage in peaty swamps (the mineral slicks in peaty swamps are often associated with iron toxicity). Fertilization with large amounts of phosphorus and potassium can be effective, although application of nitrogenous fertilizer generally aggravates the symptoms (since nitrogen is relatively available to the plant already, and the presence of nitrogen in the absence of phosphorus induces the symptoms). The most effective treatment in any case is selection of iron-toxicity-resistant varieties. Certain varieties (often traditional varieties) are able to flourish in iron-toxic soils, and they offer the most practical and economical solution to the problem.

CHAPTER 17

HARVESTING, THRESHING, DRYING, STORAGE

Introduction

The final steps in producing a crop of rice -- harvesting, threshing, drying, and storage -- often are taken for granted by the extension agent. It is natural to assume that the major part of the work lies in growing the crop, and that farmers will know what to do once the grains have ripened. But this is a mistaken assumption. The fact is that a large percentage of the crop can be (and often is) lost through improper harvesting, threshing, drying, and storage practices. This chapter describes the traditional methods of processing and storing rice and includes ideas for improvement.

Outline of Contents

I. Harvesting
II. Threshing
III. Par-boiling
IV. Drying
V. Storage

I. Harvesting

Most harvesting problems in Sierra Leone can be attributed to the fact that irrigated rice tends to ripen irregularly. At the end of the rainy season, when most varieties mature, frequent rains and a lack of continuous sunshine protract the grain ripening process and make difficult proper timing of harvesting, since grains even on the same panicle ripen at varying rates. If the crop is harvested too early, many green grains will be lost, because the high water content will lead to rotting. If, on the other hand, the crop is harvested too late, the rice will over-ripen and easily shatter. Furthermore, the unnecessary delay will expose the grains to increased bird attack, which can be devastating.

As harvest time approaches, the plants should be inspected daily, particularly the panicles on the most mature tillers. The proper time to harvest is when approximately 85% of the panicles are ripe. "Ripe" means that 90% of the spikelets are golden and hard, yet not so dried out as to shatter easily. The lowermost spikelets on each panicle will ripen last, but even they should be at least at the hard dough stage. The color of the leaves and stems should not be used as an indicator of the ripeness of the grains, since many varieties tend to have some green stems and leaves even when the grains are fully ripened.

Although grain ripening cannot be fully controlled by the farmer (climate and varietal characteristics will always be the major determinants), drain the plots 7-10 days before anticipated harvesting, i.e., when most of the grains are at the hard dough stage. This will contribute to even drying and facilitate harvesting by making it easier to walk inside the plots.

The traditional method of harvesting practiced throughout most of Sierra Leone involves panicle cutting. Harvesters grasp each stem several inches below the lowermost spikelets and cut it with a small straight knife. The panicle is retained and added to the growing bundle held in the hand. When the bundle becomes awkwardly large, it is tied together with a wisp of straw and carried out of the swamp. The chief advantage of panicle cutting is that the straw remains behind in the field. Bundles of rice produced by panicle cutting are easy to transport, easy to store, and easy to thresh. However, panicle cutting has several distinct disadvantages: it is very time-consuming, and since each panicle is handled frequently many grains shatter (fall to the ground).

In some areas of Sierra Leone, harvesting is done with the sickle. Sickle harvesting, popular in Asia, is very fast, since entire bunches of stems are grasped and cut in one swift motion. However, sickle harvesting requires the use of threshing machines -- either the pedal thresher or the threshing table. At present few farmers possess threshing machines or know how to build them, so sickle harvesting remains relatively unpopular.

II. Threshing

Rice that has been harvested by traditional panicle cutting is very easily threshed, since very little straw remains with the grains. The harvested bundles of rice are placed on a clean, hard surface and beat with sticks to separate the grains from the straw (dried leaves and stems). Frequently the threshers will walk over the bundles to speed the process. If any grains remain clinging to the straw, they are separated by pounding in wooden mortars.

Rice that has been harvested by sickle cutting must be threshed by other means, since the grains must be separated from a relatively large amount of straw. Usually a threshing machine is used to increase efficiency. The pedal thresher is a revolving drum (often an old oil drum) studded with nails or wire hoops which strip the grains from the panicles when bundles of rice are held against the moving drum, The pedal thresher is effective and fast, and it can be moved from plot to plot to eliminate extensive transportation of the cut plants. The major disadvantage of the pedal thresher is its price (about Le 150, or $150), which makes it too expensive for individual private ownership. However, farmers associations have been known to share pedal threshers with good results, since in most cases each individual's entire crop can be harvested and threshed in a few days. Another threshing device, the threshing table, is a slatted table constructed of bamboo, wood, or any suitable locally-available materials. Sheaves of rice are beaten against the table surface, dislodging the grains to drop through the slats into the collection area below. Threshing tables work best with those varieties in which the grains separate easily from the panicle, but the crop must be extremely dry for threshing to be effective.

III. Par-Boiling

In some parts of Sierra Leone, an intermediate step in the processing of rice is par-boiling. Par-boiling improves storage quality of the grain and consequently is popular among farmers who produce rice for market. Although techniques vary, par-boiling usually involves soaking the grain in water and steaming over a slow fire in covered pots. Par-boiling has several effects:

- cracks in the grain are "melted" together, leaving fewer broken grains and resulting in reduced loss during milling.
- several of the thin protein layers underlying the husk are boiled into the endosperm, thus increasing the protein content of the crop.
- the grain becomes significantly hardened, making par-boiled rice less susceptible to insect attack.
- the grain's tendency to absorb moisture from the air decreases, so that par-boiled rice keeps longer in storage.
- the husk soften and cracks during par-boiling, making it easier to mill.

But par-boiling also has disadvantages:

- par-boiling is labor-intensive
- par-boiling alters the sight, smell, taste, and texture of the rice and generally decreases its eating quality.
- par-boiled rice is harder and therefore takes longer to cook.

When it comes to the question of whether or not to parboil, there is no such thing as a "recommended" practice. Depending on the circumstances, par-boiling may or may not be economical and/or desirable. If grain loss during milling, protein content, or storage quality are important to the farmer, par-boiling may be preferred. If labor considerations, eating quality, or cooking time are important, the rice may best be left rough.

V. Drying

Before milling and storage, rice must be dried thoroughly. Rice which is not dried properly may crack during milling, or spoil during storage. At the time of harvesting, rice usually has a moisture content of 20-26%. This must be reduced to 12-14% before milling or storage can safely occur.

After threshing, the rice should be spread in the sun to dry. Constant turning is necessary to ensure slow, even drying and prevent cracking. Two to three days uninterrupted sunshine will suffice. Farmers often bite the grain to test for dryness (and usually they have a pretty good sense of what they're doing), but the extension agent may want to resort to this simple test:

1) Place in a small glass jar (with a screw top) a handful of grains.
2) Add a spoonful of ordinary salt and seal the top.
3) Store 24 hours.
4) After 24 hours, examine the contents of the jar. If the salt clumps together, the rice is too wet to mill or store. If the salt remains well dispersed, the rice has a moisture content of 15% or less and can safely be milled or stored in bags.

V. Storage

Rice harvested by panicle cutting traditionally is stored up in the rafters of the farmhouse or kitchen. The bundles are transported from the fields and stacked on reed mats high up off the ground, often over the cooking area so that smoke will sift in among the grains to assist drying and discourage insects. Where bags are readily available, the rice is often threshed and bagged for storage.

Rodent attack is generally a major problem. Since storage facilities are constructed of mud adobe and/or wood, rats easily gain access to feed on the rice. It is difficult to estimate accurately the annual crop loss to rodents, but 15% seems reasonable. In some instances, the loss is probably a good deal higher.

The key to effective grain storage lies in the construction of proper storage facilities. A good storage facility should be:

- plastered inside and out
- well ventilated
- well lit
- dry
- clean
- cool
- rat-proofed (heavy screen over windows and ventilation shafts)

After proper drying, threshed rice should be packed in bags and stored on wooden pallets in the storage facility. Instruct the farmer to stack the bags so as to allow good ventilation, since free air movement between the bags will prevent mildew and/or spoilage. Do not allow the bags to come into direct contact with the floor or walls, since moisture tends to condense where there is contact. If they are available, set rat traps (or get a cat!). Encourage the farmer to check the rice periodically for signs of spoilage and/or pest infestation.

CHAPTER 18

YIELD CALCULATION

Introduction

Through analysis of comparative yields, the farmer and/or extension agent can determine which of the available rice varieties is best suited to local swamp systems and farming practices. Farmers are generally very shrewd at estimating yields, but they rarely quantify their estimations into standardized units of measurement. This chapter describes a straightforward, quick, and reasonably accurate method of yield calculation which will enable the extension agent to keep track of local yields for purposes of comparison and planning.

Outline of Contents

I. Farmers' Estimations
II. Yield Calculation

I. Farmers' Estimations

Just because a farmer may be unable to perform mathematical computations, do not assume that s/he has no accurate sense of crop yields. Never make the mistake of underestimating the knowledge of farmers, who after years and years of growing rice tend to become shrewd economists in their own right. Farmers pay very careful attention to yields (their livelihood and in fact their very survival depend on them), and although often they develop their own particular system of accounting, generally they know exactly how each crop yielded relative to other crops grown in other years. Some farmers count the number of bundles harvested, others keep track of numbers of bags filled, still others measure in terms of bushels of grain. Whatever the methodology, the farmer ends up with a pretty good idea of how well the crop yielded, and this information helps in planning for the future.

The extension agent requires a more quantitative and standardized method. It is important that yield calculations be quantitative (expressable in precise numbers) so that actual values may be compared from swamp to swamp, year to year, variety to variety. It is important that the method be standardized so that in every case measurement is made in exactly the same way.

II. Yield Calculation

Note: Since the method of yield calculation described below requires a certain amount of mathematics, it will not always be possible to teach it to farmers. Nor will this be necessary, since for their own accounting purposes farmers can perfectly well continue to rely on their time-tried methods. However, it may be a good idea to teach the method to other extension agents. As agriculturalists, they will be working in more than just one farming system, and it will be useful for them to know how to calculate yields for comparative purposes.

Calculating yields is a two-step process involving sampling the crop and calculating the yield.

1. Sampling the Crop

Sampling a crop of rice means measuring the yield of a small fraction of the total crop area. The sample should be representative of the crop as a whole (i.e., taken from an "average" section, not from a noticably lush section, nor from a section in which there has been unusual crop damage). The sample should also be large enough to be accurate -- generally 10m^2 is considered satisfactory. For ease of measurement, harvest ten "mini-samples" of 1m^2 each to add up to the total sample of 10m^2. Within the crop area to be sampled, peg out ten "mini-samples" of 1m^2 each. Cut all the panicles within the "mini-samples" and collect them in one place. Thresh the grains, being careful not to lose any (a small error in sampling may lead to a large error in calculating the yield). Sun-dry the grains for 2-3 days, or until the moisture content is close to the 14% considered suitable for storage. (It is important that the grains be well-dried, since undried grains are considerably heavier and will produce inaccurate yield figures). Winnow out all unfilled grains and carefully weigh the remaining rice.

2. Calculating the Yield

If taken exactly as described above, the sample will contain the yield of 10m^2 of the total crop area. Since yields are generally expressed in terms of kg/ha (kilograms of grain per hectare), the problem now is to convert the yield figures derived from the sample (kg/$10m^2$) into the standard units of measurement (kg/ha). Since 1ha = $10000m^2$, the sample area constitutes $\frac{10}{10000}$ ha, or $\frac{1}{1000}$ ha. Therefore, to determine the average crop yield in kg/ha, simply multiply the weight of the sample by 1000.

Example: Careful sampling of ten $1m^2$ "mini-samples" results in 550g (.55kg) of dry grain. What is the yield of the crop in terms of kg/ha?

Weight of sample = .55kg
Area of sample = $10m^2$

Yield in kg/ha = $\frac{.55kg}{10m^2}$ x 1000 = 550kg/ha.

Note: Yields measured in kg/ha can be converted into lbs/acre or bushels/acre using the following conversion rates:

1 kg = 2.2 lbs
1 lb = .453 kg
1 bushel = 60 lbs
1 bushel = 27.18 kg

1 ha = 10000 m^2
1 ha = 2.47 acres
1 acre = 43560 f^2
1 acre = 405 ha

References

Rice Production Manual (Revised Edition, 1970) Compiled by the University of the Philippines College of Agriculture in cooperation with the International Rice Research Institute (IRRI)

The definitive handbook for the extension agent working with upland or irrigated rice; includes comprehensive information about all aspects of rice cultivation, including plant growth and development, soil chemistry, response to fertilization, water management practices, etc. Available by direct mail order from: Salesroom, Department of Agricultural Communications (DAC), University of the Philippines, College of Agriculture, College, Laguna, Republic of the Philippines. One copy available through ICE to Peace Corps in-country resource centers/libraries.

Soils, Crops, and Fertilizer Use - A Guide For Peace Corps Volunteers, by Dave Leonard (ICE Reprint #8, Peace Corps)

A condensed, readable, information-packed booklet dealing with technical aspects of soil chemistry, plant nutrient uptake, and fertilization; a valuable complement to this manual, especially for those lacking formal training in agriculture. Available to PCVs through ICE, Peace Corps, 806 Connecticut Avenue, N.W., Washington, D.C. 20525.

Apply Pesticides Correctly (U.S. Department of Agriculture, U.S. Environmental Progection Agency)

Although self-described as "A guide for commercial applicators," this pamphlet provides excellent background information useful to the extension agent; includes coverage of types of pests, pest control methods, pesticides, labels and labeling, pesticide use, laws and regulations; recommended particularly for those with little experience with pesticide use. Available to PCVs from ICE (see above).

Pest Control in Rice (PANS Manual No. 3 - Centre for Overseas Pest Research, London)

The definitive guide to pest control in rice; very comprehensive, including discussion of weeds, diseases, molluscs, nematodes, crustacea, insects and mites, birds, and rodents. Address requests for single copies to: Centre for Overseas Pest Research, PANS Office, College House, Wrights Lane, London W8 5SJ, UK.

Glossary of Terms

BUND - A raised dirt bank built in a swamp to block water.

HEADBUND - A large earthen dam constructed at the head of a developed swamp.

PADDY - A bunded, well leveled field with almost perfect water control. A paddy is the ultimate land development goal for high level rice production by individual farmers.

PUDDLING - A leveling process used to break down the structure of wet soils.

SWAMP - A depression in the landscape which can vary from a shallow to a deep waterlogged area which may or may not dry out during the year.

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